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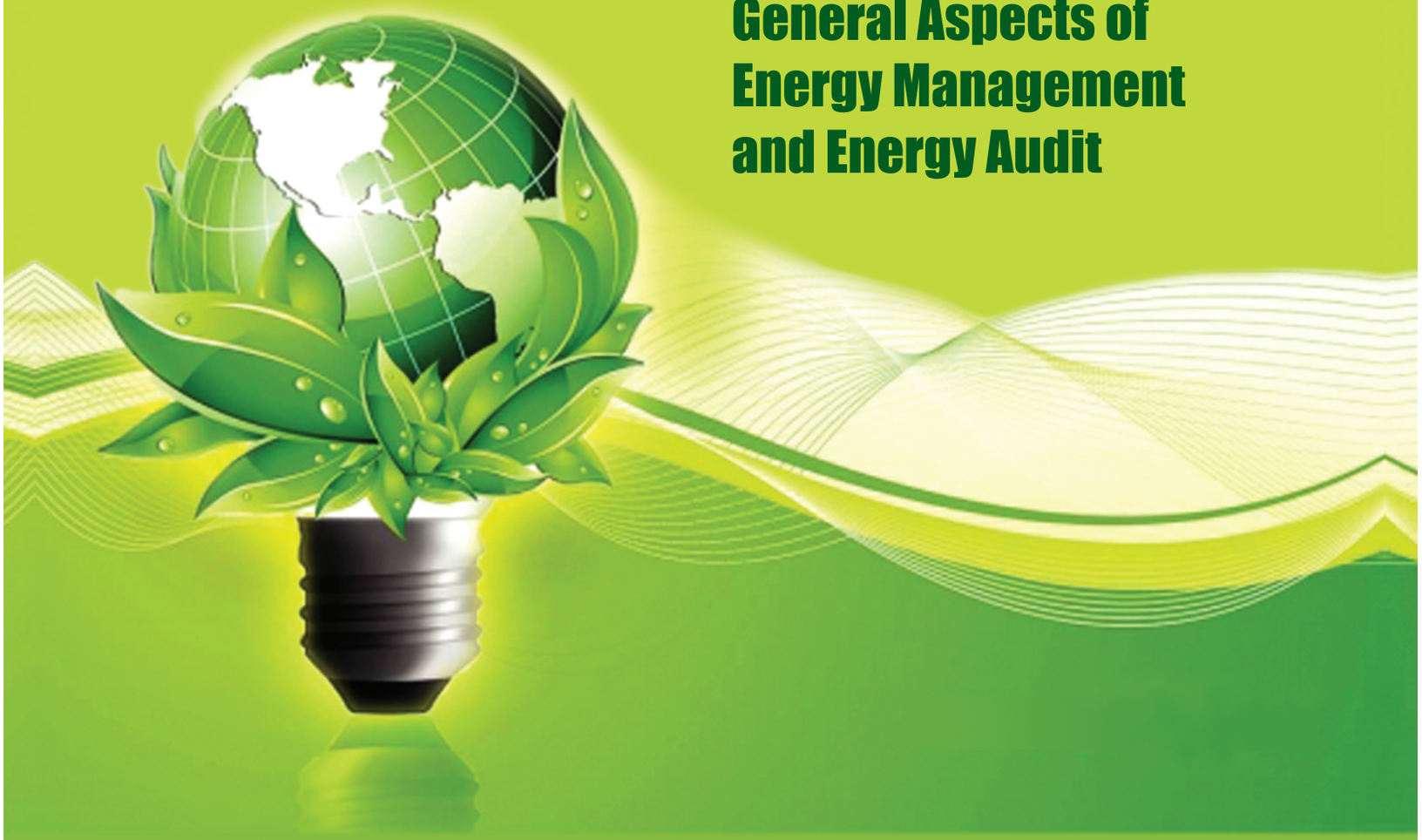
General Aspects of Energy Management and Energy Audit



GUIDE BOOK

for

NATIONAL CERTIFICATION EXAMINATION

FOR ENERGY MANAGERS AND ENERGY AUDITORS

Bureau of Energy Efficiency

(A Statutory Body under Ministry of Power, Government of India)

4th Floor, Sewa Bhawan, R. K.Puram, New Delhi - 110 066

www.bee-india.nic.in

FOURTH EDITION, 2015

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PREFACE

National Certification Examination for Energy Managers and Energy Auditors aims to develop qualified professionals in the field of energy conservation in India.

At the initiative of Bureau of Energy Efficiency (BEE), for meeting the requirements of National Certification Examination for Energy Managers and Energy Auditors, Dr. Ambedkar Institute of Productivity, Chennai, the training institute of National Productivity Council of India has prepared four guide books in respect of four examinations as follows:

Guide Book	Examination Paper	Topic
Book-1	**Paper-1**	**General Aspects of Energy Management and Energy Audit**
Book-2	Paper-2	Energy Efficiency in Thermal Utilities
Book-3	Paper-3	Energy Efficiency in Electrical Utilities
Book-4	Paper-4	Energy Performance Assessment for Equipment and Utility Systems

This book –1 on General Aspects of Energy Management and Energy Audit focuses on Global and Indian energy scenario, Energy management and Auditing principles, guidance for implementation, Environmental implications and concerns in energy use. It also contains guidelines for conducting energy audit and for setting up effective energy management system in industry.

These books have been prepared with material support from the various resources referenced at the end of each chapter. We trust that these books, besides its intended purpose, will also help in enhancing the knowledge base of practicing engineers and managers in understanding and applying energy efficiency techniques.

We hope that this revised edition, incorporating recent developments and practices, will be of use to the prospective energy auditors, managers and other relevant energy efficiency professionals. We invite your valued suggestions and comments, which may be mailed to **guidebooks@em-ea.org**

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MESSAGE

India's economic growth depends on the long-term availability of energy from sources that are affordable, accessible and environmentally friendly. Increasing demands for fossil fuels have led to over exploitation of natural resources with adverse impacts on environment and the resultant health issues.

Energy efficiency and its conservation is one of the most cost effective measures to bridge the gap between demand and supply, and to mitigate the environmental impacts of rapid development.

It is heartening to note that the guide books prepared for the National Certification Examination for energy managers and auditors has caught the attention of a wide cross section of the engineering fraternity, not only in India but also in many countries around the world. Many of the techniques and technologies enumerated in these guide books towards enhancing energy efficiency have been put to practice and rich dividends have been realized. Thus these books besides meeting the requirements of the examination are also serving as a manual for practicing engineers.

I commend the efforts put in to prepare such a practical and comprehensive compilation. My best wishes to the users of these books.

(Pradeep K.Sinha)

ENERGY IS LIFE
BEE
CONSERVE IT

ऊर्जा दक्षता ब्यूरो
(भारत सरकार, विद्युत मंत्रालय)

BUREAU OF ENERGY EFFICIENCY
(Government of India, Ministry of Power)

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MESSAGE

The guide books for National Certification Examination for Energy Managers and Energy Auditors are an enthusiastic celebration of a wide variety of topics related to energy efficiency, especially those which are of practical nature, intricate structure and timely relevance. A glance through the pages of this book will show that it is an unusual type of publication. Though primarily intended for the purpose of being a study material for the examination these guide books have been found to be an out and out a practical guide to implementing energy savings measures in industry and establishments. That they have also been adopted by the energy efficiency promotion organisations of other countries is a testimony to the efficacy of these guide books. Also many of the Indian universities have adopted these books for Post Graduate programmes in energy management.

Written by a group of experienced professionals practicing energy efficiency the books explore the depth and breadth of various possibilities for saving energy in a wide gamut of processes and equipment. Guides such as these are no replacement for the necessary hard work required to realize the potential of energy efficiency but they can certainly help you ensure that your efforts are focused and effective.

I wish all the readers the very best.

(Ajay Mathur)

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ACKNOWLEDGEMENT

Energy efficiency has assumed a critical role in our pursuit of sustainable development. The gains from energy efficiency have been harnessed the world over and India is no exception. Information from the industry and other establishments reveal the rapid strides made in the area of energy efficiency in our country. Examples of industries which have achieved this potential are projected in the energy conservation award programme of Government of India.

As the low hanging fruits appear to have been picked up the path to success in energy management is getting steeper and steeper. More and more information, innovations and knowledge are required to further exploit the energy conservation potential. The continuous efforts to upgrade and refine the guide books for National Certification Examination for Energy Managers and Energy Auditors are aimed at equipping the reader with the resources to identify and implement various energy conservation measures. Through the system of examination we have been able to build sufficient skilled manpower in the area of energy efficiency. We are pleasantly surprised by the enormous interest evinced in the examination from all corners

The unwavering support for the development of these guide books and constructive comments from various quarters about their contents, have been invaluable.

(Bhaskar J. Sarma)

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Book-1 GENERAL ASPECTS OF ENERGY MANAGEMENT AND ENERGY AUDIT

Chapter – 1 Energy Scenario

Chapter – 2 Energy Conservation Act, 2001and Related Policies

Chapter – 3 Basics of Energy and its Various Forms

Chapter – 4 Energy Management and Audit

Chapter – 5 Material and Energy Balance

Chapter – 6 Energy Action Planning

Chapter – 7 Financial Management

Chapter – 8 Project Management

Chapter – 9 Energy Monitoring and Targeting

Chapter – 10 Energy Efficiency and Climate change

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BOOK 1 - GENERAL ASPECTS OF ENERGY MANAGEMENT AND ENERGY AUDIT

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Chapter 1

Energy Scenario

Learning Objectives

In this chapter you will learn about

- Types of energy sources
- Life of energy sources
- Energy scenario in India
- Energy vs economic growth
- Energy policies, pricing and reforms
- Linkage between energy use and environment
- Need for energy conservation
- Energy security and strategies for future

1. ENERGY SCENARIO

Commercial and non-commercial energy, Primary energy resources, Commercial energy production, Final energy consumption, Indian energy scenario, Sectoral energy consumption, Energy needs of growing economy, Energy intensity on purchasing power parity (PPP) basis, Long term energy scenario, Energy pricing, Energy security, Energy strategy for the future, Energy conservation and its importance

1.1 Introduction

Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes critical importance in view of the ever-increasing energy needs, requiring huge investments to meet them.

The consumption of energy is increasing at a fast pace while available resources remain limited. The global need for energy is increasing on an average by about 2.4% every year. Out of the total amount of primary energy, over 85% comes from fossil fuels. The current consumption of fossil fuels, particularly oil, is not sustainable in the long term.

Energy consumption also has a significant impact on our natural environment. There is clear evidence that climate change is caused by human activity, mostly related to the use of energy.

Energy, that we use, can be classified into several types based on the following criteria:

- Primary energy and secondary energy
- Commercial and non commercial energy
- Renewable and non-renewable energy

1.2 Primary and Secondary Energy

Primary energy refers to all types of energy extracted or captured directly from natural resources. Primary energy can be further divided into two distinctive groups:

- Renewable (solar, wind, geothermal, tidal, biomass, hydel etc.)
- Non-renewable (fossil fuels: crude oil and its products, coal, natural gas, nuclear, etc.)

The primary energy content of all fuels is generally expressed in terms of toe (tonne of oil equivalent) and is based the following conversion factor.

One tonne of oil equivalent (toe) = 1 x 10^7 kcal = 11630 kWh = 41868 MJ

Primary energy sources are mostly converted in industrial utilities into secondary energy sources; for example coal, oil or gas converted into steam and electricity. Primary energy can also be used directly. Some energy sources have non-energy uses, for example coal or natural gas can be used as a feedstock in fertiliser plants. Primary energy is transformed in energy conversion process to more convenient forms of energy such as electricity, steam etc. These forms of energy are called secondary

energy. The major primary and secondary energy sources are shown in Figure 1.1.

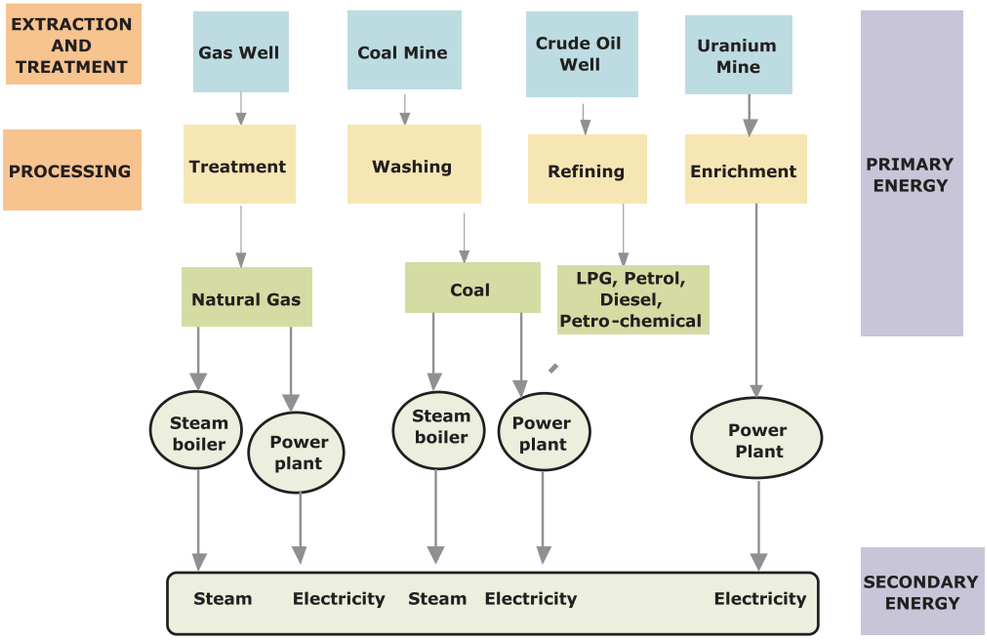


Figure 1.1 Major Primary and Secondary Energy Sources

1.3 Commercial Energy and Non Commercial Energy

Commercial Energy

Energy that is available in the market for a definite price is known as commercial energy. No matter what the method of energy production is, whether it is from fossil fuels, nuclear or renewable sources, any form of energy used for commercial purposes constitutes commercial energy.

By far, the most important forms of commercial energy are electricity, coal, refined petroleum products and natural gas. Commercial energy forms the basis of industrial, agricultural, transport and commercial development in the modern world. In the industrialized countries, commercial fuels are predominant sources of energy not only for industrial use, but also for many household needs.

Examples: Electricity, lignite, coal, oil, natural gas etc.

Non-Commercial Energy

Any kind of energy which is sourced within a community and its surrounding area, and which is not normally traded in the commercial market is termed as non-commercial energy.

Non-commercial energy sources include fuels such as firewood, cattle dung and agricultural wastes, which are traditionally gathered, and used mostly in rural households. These are also called as traditional fuels. Non-commercial energy is often ignored in compiling a country's energy statistics.

Examples: Firewood and agro waste in rural areas, solar energy for water heating, electricity generation, and for drying grain, fish and fruits; animal power for transport, threshing, lifting water for irrigation, crushing sugarcane etc.; wind energy for lifting water and electricity generation.

1.4 Renewable and Non-Renewable Energy

Renewable energy is the energy obtained from natural sources which are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power (see Figure 1.2). The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.

A non-renewable resource is a natural resource which cannot be produced, grown, replenished, or used on a scale which can sustain its consumption rate. These resources often exist in a fixed amount, or are consumed much faster than nature can create them. Natural resources such as coal, oil and natural gas take millions of years to form and cannot be replaced as fast as they are being consumed now. These resources will deplete with time.

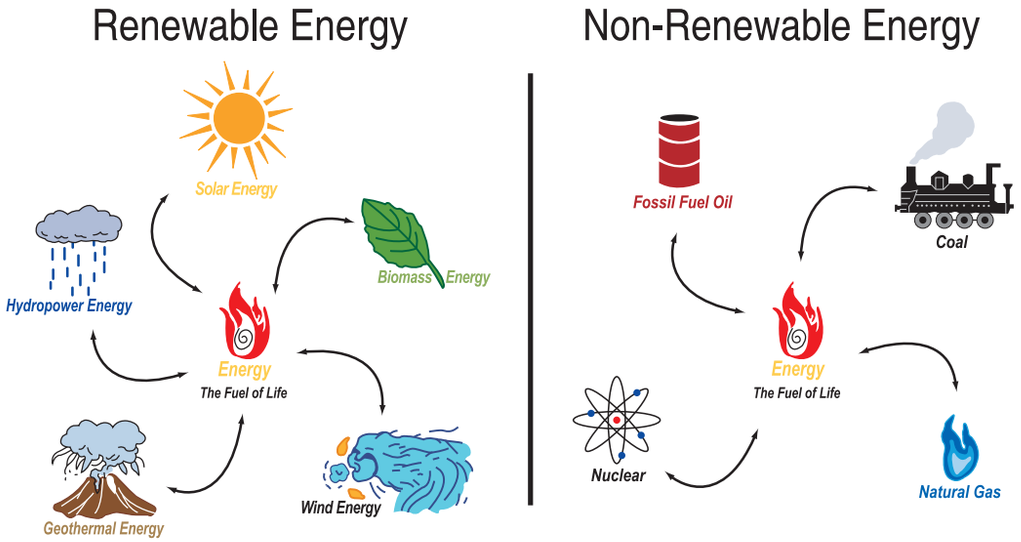


Figure 1.2 Renewable and Non-Renewable Energy

1.5 Global Primary Energy Reserves and Commercial Energy Production

Coal

Coal is the most abundant and geographically dispersed fossil fuel and exists as peat, brown coal (lignite), sub-bituminous, bituminous and anthracite (see Figure 1.3).

It has been estimated that there are around 892 billion tonnes of proven coal reserves worldwide. Proved coal reserves are shown for anthracite and bituminous (including brown coal) and sub-bituminous and lignite. There is enough coal to last around 113 years at current rates of production (Source: BP Statistical Review of World Energy, 2014).

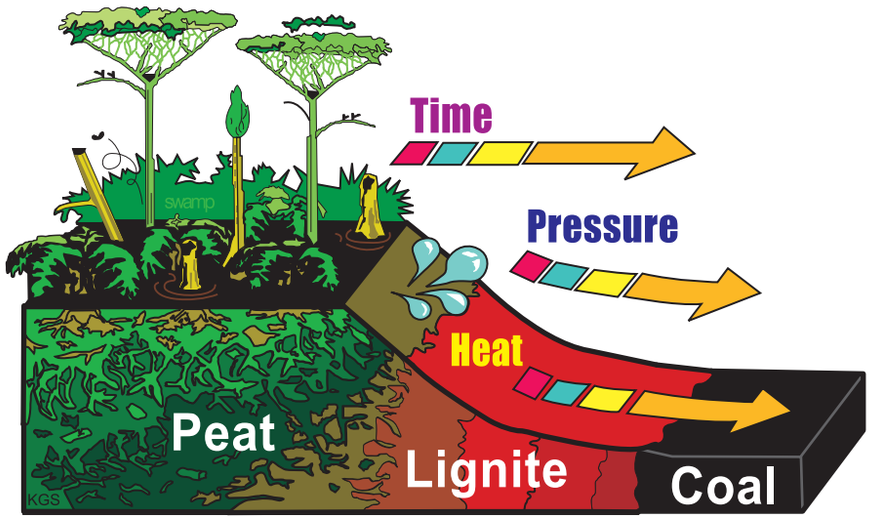


Figure 1.3 Formation of Coal

Reserves/Production (R/P) - If the reserves remaining at the end of the year are divided by the production in that year, the result is the length of time that the remaining reserves would last if production were to continue at that level.

Coal reserves are available in almost every country worldwide with recoverable reserves in around 75 countries. The largest coal reserves are available in the USA, followed by Russia, China, Australia and India (see Table 1.1).

Table 1.1 Proven Coal Reserves by Country by end of 2013

Country	Million tonnes	Share of total, %	Reserve / Production (R/P in years)
US	237295	26.6	266
Russian Federation	157010	17.6	452
China	114500	12.8	31
Australia	76400	8.6	160
India	60600	6.8	100
Others	245726	27.6	
World	**891531**	100	**113**

Source: BP Statistical Review of World Energy June 2014

Despite its poor environmental credentials, coal remains a crucial contributor to energy supply in many countries. Although countries in Europe, and to some extent North America, are trying to shift their consumption to alternative sources of energy, any reductions are more than offset by the large developing economies, primarily in Asia, which are powered by coal and have significant coal reserves. China alone now uses as much coal as the rest of the world.

The top coal producers are given in Table 1.2. Most of the demand for coal comes from power sector.

Table 1.2 Top Coal Producers in Million Tonnes (by end of 2013)

Country	Million tonnes	Share of total, %
China	3680.0	47.4
US	892.6	12.9
Indonesia	421.0	6.7
Russian Federation	374.1	4.3
India	605.1	5.9
South Africa	256.7	3.7
Others	1666.9	19.1
World	**7896.4**	100

Source: BP Statistical Review of World Energy June 2014

Oil

The global proven oil (crude oil) reserve was estimated to be 1687.9 billion barrels by the end of 2013. Almost, 48 % of the proven oil reserves are in the Middle East. Saudi Arabia has the largest share of the reserve with 15.8%. Top proven world oil reserves (in billion barrels) are given in Table 1.3.

Table 1.3 Proven World Oil Reserves by end of 2013

Country	Billion tonnes	Billion barrels	Share of total, %	R/P years
Venezuela	56.6	298.3	17.7	> 100
Saudi Arabia	36.5	265.9	15.8	63.2
Canada	28.1	174.3	10.3	> 100
Iran	21.6	157	9.3	> 100
Iraq	20.2	150.0	8.9	> 100
India	0.8	5.7	0.3	17.5
Others	74.4	636.7	37.7	-
World	**238.2**	**1687.9**	**100**	**53.3**

Source: BP Statistical Review of World Energy June 2014

(1 barrel ≈ 160 litres)

Saudi Arabia was the largest oil producer in the world (end of 2013) followed closely by Russian Federation and US. Although the United States ranks third in terms of oil production, it only ranks tenth in terms of proven oil reserves. The top oil producing countries in 2013 are given in Table 1.4. As against the top producing countries (end of 2013), India's share is 42 million tonnes and share of total is 1%.

Table 1.4 Top Oil Producing Countries by End of 2013

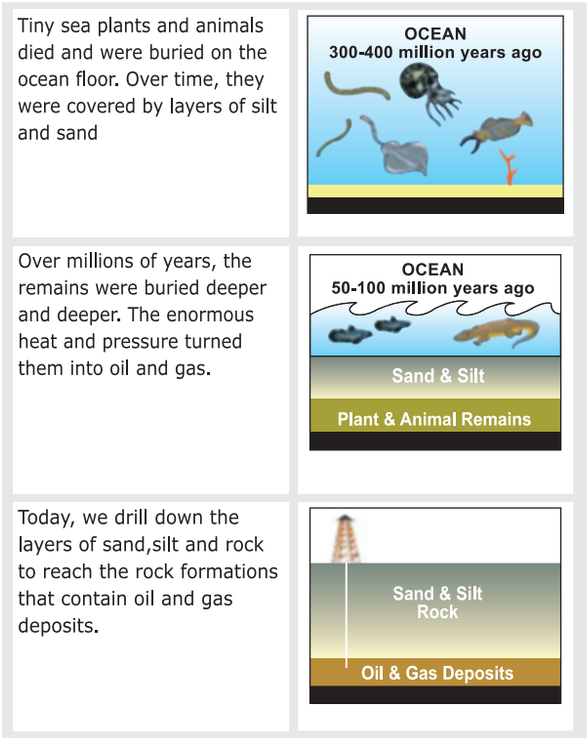
Region	Million tonnes per year	Share of total, %
Saudi Arabia	542.3	13.1
Russia	531.3	12.9
US	446.2	10.8
China	208.1	5.0
Canada	193	4.7
Iran	166.1	4.0
Iraq	153.2	3.7
Nigeria	111.3	2.7
Others	2351.5	43.1
World	**4130.2**	**100**

Source: BP Statistical Review of World Energy June 2014

If production continues at today's rate, many of the major producers such as US, Russia, China will have their oil fields largely depleted within a decade. At that point of time, world may have to depend mostly on Middle East for oil.

The Middle East overall reserves-to-production ratio for conventional oil (average of about 78 years) is much higher than that of non-Middle East countries.

Since unconventional oil resources, including oil shale, oil sands, extra heavy oil and natural bitumen are taken into account as oil, the global oil reserves will be four times larger than the current conventional reserves. Oil still remains the premier energy resource with a wide range of possible applications. Its main use however, will be shifting towards transport and the petrochemical sector. In future oil's position at the top of the energy ladder will face a strong challenge from other fuels such as natural gas.



Oil shale generally refers to any sedimentary rock that contains solid bituminous materials (called **kerogen**) that are released as petroleum-like liquids when the rock is heated in the chemical process of pyrolysis.

Oil sands (also known as Tar sands) are a combination of clay, sand, water, and **bitumen**, a heavy black viscous oil. Tar sands can be mined and processed to extract the oil-rich bitumen, which is then refined into oil.

Natural bitumen is the portion of petroleum that exists in the semi-solid or solid phase in natural deposits. In its natural state it usually contains sulphur, metals and other non-hydrocarbons.

Extra Heavy Oil is the portion of heavy oil having an API gravity of less than 10°.

Natural Gas

Natural gas is a gaseous fossil fuel consisting primarily of methane but also includes small quantities of ethane, propane, butane and pentane. Before natural gas can be used as a fuel, it undergoes extensive processing for removing almost all constituents except methane. It ranks third after crude oil and coal in terms of usage but has clearly gained in usage. Natural gas has been making a very significant contribution to world energy basket during the past three decades.

Natural gas resources are large, but, like oil, they are highly concentrated in a few countries and fields**.** The global proved gas reserve was estimated to be around 186 trillion cubic metres by the end of 2013. This is equal to around 55 years of current production. Iran has the largest share of the reserve followed by Russia and Qatar. India has only about 0.7% of global natural gas reserves. The global distribution of proved natural gas reserves is given in Table 1.5.

Table 1.5 Natural Gas Proven Reserves: Top Countries (by end of 2013)

Country	Trillion cubic metres	Share of total, %	R/P (years)
Iran	33.8	18.2	> 100
Russia	31.3	16.8	51.7
Qatar	24.7	13.3	> 100
Turkmenistan	17.5	9.4	> 100
US	9.3	5	13.6
Others	69.1	37.3	-
World	**185.7**	**100**	**55.1**

Source: BP Statistical Review of World Energy June 2014

US is the world's largest natural gas consumer at around 22% followed by Russia at around 12%. Other top gas consuming countries include Iran, China, and Saudi Arabia. Natural gas is extensively used for power generation, transportation and heating buildings in most countries. It would require creation of adequate physical infrastructure to enable mass usage in energy hungry countries like India and China.

At current R/P ratio, World oil and gas reserves are estimated at just 53 years and 55 years respectively. Coal is likely to last for 113 years.

Global Primary Energy Consumption

The global primary energy consumption at the end of 2014 was equivalent **to 12730 Million tonnes oil equivalent**. The share of oil is the largest at 33% followed by coal and natural gas with 30% and 24% respectively. The demand for natural gas in future will increase as industrialized countries take strong action to cut CO_2 emissions. The Table 1.6 shows the breakup of various constituents of primary energy consumption (Million Tonnes of Oil Equivalent, Mtoe) worldwide.

Table 1.6 Global Primary Energy Consumption by Energy Source

Oil	Natural gas	Coal	Nuclear Energy	Hydro-Power	Renewable Energy	Total, Mmtoe
4185.1	3020.4	3826.7	563.2	855.8	279.3	12730.4
33%	24%	30%	4%	7%	2%	

Source: BP Statistical Review of World Energy June 2014

The primary energy consumptions for some of the developed and developing countries are shown in Table 1.7. It may be seen that India's absolute primary energy consumption is only about 4.7 % of the world, 26% of USA's and 21% of China's consumption.

Table-1.7 Primary Energy consumption at the end of 2013

	Million tonnes of oil equivalent (Mtoe)							% of Share
Country	Oil	Natural gas	Coal	Nuclear Energy	Hydro-Power	Renewable Energy	Total	
China	507.4	145.5	1925.3	25	206.3	42.9	2852.4	22.4
US	831.0	671.0	455.7	187.9	61.5	58.6	2265.8	17.8
Russia	153.1	372.1	93.5	39.1	41	0.1	699	5.5
India	175.2	46.3	324.3	7.5	29.8	11.7	595.0	4.7
Japan	208.9	105.2	128.6	3.3	18.6	9.4	474.0	3.7
Germany	112.1	75.3	81.3	22.0	4.6	29.7	325.0	2.6
Others	2197.4	1198.3	818	278.4	494	126.9	5519.2	43.3
World	**4185.1**	**3030.4**	**3826.7**	**563.2**	**855.8**	**279.3**	**12730.4**	**100**

Source: BP Statistical Review of World Energy, June 2014

1.6 Final Energy Consumption

Final energy is the form of energy available to the end user following conversion from primary energy. Final Energy consumption, measured in Million tonnes of oil equivalent (Mtoe) is the sum of the energy consumption in the end-use sectors. Energy used for transformation and for own use by the energy producing industries are excluded. Thus, final consumption reflects energy delivered to the

consumers. Globally, industry consumes almost 50 % of final consumption, followed by Transportation (20 %), Residential (18%), and Commercial (12%) (Source: U.S. Energy Information Administration).

1.7 Indian Energy Scenario

The annual energy consumption in India is 595 Million tonnes oil equivalent compared with the world energy consumption of 12,730 Million tonnes oil equivalent in 2013.

Coal dominates the energy production mix in India, contributing to about 55% of the total primary energy production. Over the years (2008-2013), there has been a gradual increase in the share of natural gas in primary energy production and a small drop in share of oil in primary energy production. The share of commercial energy in total primary energy consumption is about 74% and share of non-commercial energy in total primary energy consumption is 26%. The primary energy consumption mix in India for 2008-09 is given in Table 1.8.

Table 1.8 Primary Commercial Energy Consumption Mix in India in 2013

Energy Type	Mtoe	% share in total primary Energy Consumption
Oil	175.2	29.5%
Natural Gas	46.3	7.8%
Coal	324.3	54.5%
Nuclear energy	7.5	1.3%
Hydro Power	29.8	5.0%
Renewable energy	11.7	2.0%
Total Primary Energy consumption	595	100.00

Source: BP Statistical Review of World Energy, June 2014

Energy Supply

Coal Sector

India has huge coal reserves of about 60.6 billion tonnes comprising of hard coal 56.10 billion tonnes (Anthracite and bituminous) and soft coal 4.5 billion tonnes (sub-bituminous and lignite). This amount to about 6.8 % of the world reserves and it may last for about **100** years at the current Reserve to Production (R/P) ratio. Indian coal reserves are mainly confined to eastern and south central parts of the country. The State of Jharkhand, and Odisha account for almost 51% of the total coal reserves in the country as on 31st March 2013.

India is one of the largest producers of coal and lignite in the world. Majority of the coal (over 80%) is mined only upto 150 - 300 m depth with open cast mining and balance 20% of coal is mined from underground mines.

The production of coal (coking and non-coking coal) and lignite is shown in the following Table 1.9.

Table 1.9 Total Production of Coal (Qty in Million tonnes)

Year	Coking coal	Non-coking coal	Coal Total	Lignite
2012-13	51.582	504.82	556.402	46.453
2011-12	51.66	488.29	539.95	42.332
2010-11	49.547	483.147	532.694	48.95

Source: Coal Directory of India, 2012 – 2013: Coal Statistics

Most of these are high ash content coal (30-45%) and the calorific value in the range of 3000 kcal/kg to 4,500 kcal/kg. The power sector consumes about 75% of the coal produced. Using the high ash coal for the power sector is a challenge in terms of achieving efficiency of consumption and environmental management of the fly ash emissions.

The coal produced in the country is not sufficient to meet the present demand of power, steel and cement sectors which are expanding their capacities. To meet this increasing gap between demand and supply, higher calorific value and low ash content coal are being imported mainly from Australia, Indonesia and South Africa based on quality as well as cost considerations. Coking coal is imported by steel sector and coke manufacturers mainly on availability and quality considerations. Coastal based power stations and cement plants are also importing non-coking coal on considerations of transport logistics and commercial reasons. Main exporter of coal to India was Indonesia followed by Australia and South Africa.

Import of coal is sharply increasing since 2011 and about 145.785 million tonnes of coal (about 20 % of the annual coal requirement) were imported during the year 2012-2013. India's coal import over the period is shown in the Table 1.10.

Table 1.10 Total Import of Coal (Qty in Million tonnes)

Year	Coking coal	Non-coking coal	Total
2012-13	35.557	110.228	145.785
2011-12	31.801	71.052	102.853
2010-11	19.484	49.434	68.918

The Government levies Clean Energy Cess or coal tax, on all the coal, peat and lignite mined within the country or imported since July 1, 2010. The Indian Government has announced the coal tax in order to generate funding for the research, development and deployment of cleaner and renewable energy technologies. A tax of Rs. 100 would be levied on every tonne of coal mined in the country as well as that imported from abroad.

However, with India already having committed (domestic commitment) to reduce its carbon intensity by 20 to 25 percent from 2005 levels by 2020, the strategy of using coal for large-scale rural electrification could hamper its efforts to achieve the carbon intensity reduction targets.

Oil Sector

India's oil reserves are estimated at 5.7 billion barrels (800 Million tonnes), which amount to only about 0.3% of the total world reserves. The main oil fields are located in the Bombay High, upper Assam, Cambay, and Krishna-Godavari basin.

Oil accounts for about 29 % of the country's primary energy consumption at the end of 2013. India's crude oil production was about 42 million metric tonnes as against the consumption of about 175.2 million metric tonnes. India's present reserve to production (R/P) ratio is only about 17.5 years.

Currently, India is the fourth largest oil-consuming country in the world. India imports over 75% of its crude oil needs, mainly from Gulf nations. In terms of sector wise petroleum products consumption, transport sector is the largest followed by domestic and industry sector.

Since the introduction of New Exploration Licensing Policy (NELP), oil and gas sector has been opened to private and foreign investments in order to bring new technologies and international best practices. During the year 2013-14 the import of crude oil was 189.238 MMT valued at Rs. 8,64,875 crores. Table 1.11 gives the crude oil import bill trend over the last few years.

Table:1.11 The import bill of crude and petroleum products

Year	Quantity (Million Metric Tonnes)	Import Bill (Rs Crore)
2010-11	163.595	4,55,276
2011-12	171.729	6,72,220
2012-13	184.795	7,84,652
2013-14	189.238	8,64,875

Source: Ministry of Petroleum and Natural Gas

Natural Gas Sector

Natural gas has become the most preferred fuel due to its inherent environmentally benign nature, greater efficiency and cost effectiveness. It is also termed as the fuel of the 21st century. When natural gas is cooled to -161^{o}C, it is transformed into Liquefied Natural Gas (LNG). This is done for ease of storage and transportation. Since liquefaction reduces the volume occupied by the natural gas by 600 times, LNG is transported in specially built ships with cryogenic tanks. Compressed Natural Gas (CNG) is made by compressing natural gas (which is mainly composed of methane [CH_4]) to less than 1% of the volume it occupies at standard atmospheric pressure. It is stored and distributed in hard containers of cylindrical or spherical shapes, at a pressure of 200–248 kg/cm^2. CNG can be used in

traditional petrol internal combustion engine vehicles that have been converted into bi-fuel vehicles (petrol/CNG).

India's gas reserves are estimated at 1.4 trillion cubic metres by end of 2013 which amounts to about 0.7% of the total World reserves. About 66 per cent of the country's production comes from offshore production, whereas the remaining 34 per cent comes from on-shore production. The bulk of onshore production comes from Assam, Gujarat, Andhra Pradesh. Under production sharing contracts, private parties have also started producing gas in some of the fields. India's present Reserves / Production (R/P) ratio is 40 years.

Natural gas accounts for only about 7.8 per cent of fuel consumption in India compared to the world average of about 24% in 2013. India's consumption of natural gas is 51.4 billion cubic metres as against the production of 33.7 billion cubic metres in 2013. India also imports natural gas in the form of LNG. LNG is received in terminals and regassified and then supplied as natural gas to the consumers. LNG projects are capital intensive.

Power generation and fertiliser industry dominate the natural gas consumption at 62% . Since gas now finds uses beyond conventional power and fertilizer sectors like automotive fuels, distributed power generation, industrial and domestic fuel, etc., the Indian Government is keen on increasing the availability of gas in the country.

A gas grid is being constructed across the country to meet the consumers' bulk and retail use. City gas supply is now covered only in a few major cities and is set to increase with India's gas infrastructure. More LNG terminals are also being developed to tap the global gas market.

The disadvantages with the use of natural gas are unpredictability in its price and uncertainty in its availability.

India's oil and gas reserves are estimated to last just 17.5 years and 40.2 years respectively at the current R/P ratio. Coal is likely to last for 100 years.

Electrical Energy Supply

The installed capacity of electric power stations in India is 2,38,743 MW as on February 2014, out of which 40195 MW is from Hydro-electric power plants, 163305 MW is from Thermal and 5780 MW from Nuclear and 29463 MW from Renewable Energy Sources. Refer Table 1.12.

The gross generation of power in the year 2013/14 was 881786 million kWh. India faces energy shortage of 3.8 % and peak shortage of 3.3% (Source: Ministry of Power)

Table 1.12 Breakup of Installed Capacity by Energy Source

Power Generation Route	Capacity (MW)	%
Total Thermal	**1,63,304.99**	**68.4**
Coal	*1,40,723.39*	58.9
Gas	*21,381.85*	9.0
Oil	*1,199.75*	0.5
Hydro	**40,195.40**	**16.84**
Nuclear	**5,780.00**	**2.42**
Renewable energy sources (small hydro, wind, biomass and others)	**29,462.55**	**12.34**
Total	**2,38,742.94**	**100.0**

Nuclear Power Supply

India currently operates 21 nuclear power units at seven locations.. The installed capacity of nuclear power plant is 5780 MW which comprises of Boiling Water Reactors and Pressurized Heavy Water Reactors. Projects are underway which can add further 6100 MW to the existing capacity. Currently, Nuclear power contributes to only about 2 per cent of the total installed capacity in India. Department of Atomic Energy plans to put up a total installed nuclear power capacity of 63,000 MW by the year 2032 in the country

India's ability to develop nuclear power is restricted as we do not have adequate supply of Uranium leading to poor operating load factor. The Uranium produced in India is 2-3 times costlier since Indian ores contain only about 0.1% Uranium compared to 12-13% in the Uranium ores mined abroad. The locally available Uranium can meet the requirement of only about 10,000 MW of nuclear power generation.

Hydro Power Supply

India is endowed with a vast and viable hydro potential for cleaner power generation. This amounts to economically viable hydro power capacity of over 84,000 MW at 60% load factor. Around 80% of this potential capacity has been identified in the Brahmaputra, Indus and Ganges basins. In addition, another 15,000 MW has been acknowledged as being potentially available in small hydro projects.

In addition to being a benign source of power, hydropower generation has the inherent ability for instantaneous starting, stopping and managing of load variations that will help in improving the reliability of the system. Hydro power also aids utilities in averaging their power procurement cost, as the generation cost reduces over time and most of the low cost power procurement of utilities comes from hydro sources. Unlike generation from fossil fuels, hydropower generation is independent of inflation.

The share of hydropower in the country's total generated units has steadily decreased over time and it stands at about 17% by 2013. In order to maintain a balance between hydro power and thermal power, the Ministry of Power has announced a policy for accelerated development of hydro power in the country. Development of small and mini hydro power at an accelerated pace is one of the tasks in the policy. The small and mini hydro projects have good potential to provide energy in remote and hilly areas where extension of grid system is uneconomical. To accelerate the development of hydro power, projects up to 25 MW have been brought under the domain of the Ministry of New and Renewable Energy (MNRE), while projects beyond 25 MW continue to remain under the of Ministry of Power.

1.8 Sector wise Energy Consumption in India

The major commercial energy consuming sectors in the country are shown in the Figure 1.4. The industrial sector consumes almost 44 % of the total commercial energy consumption followed by transport.

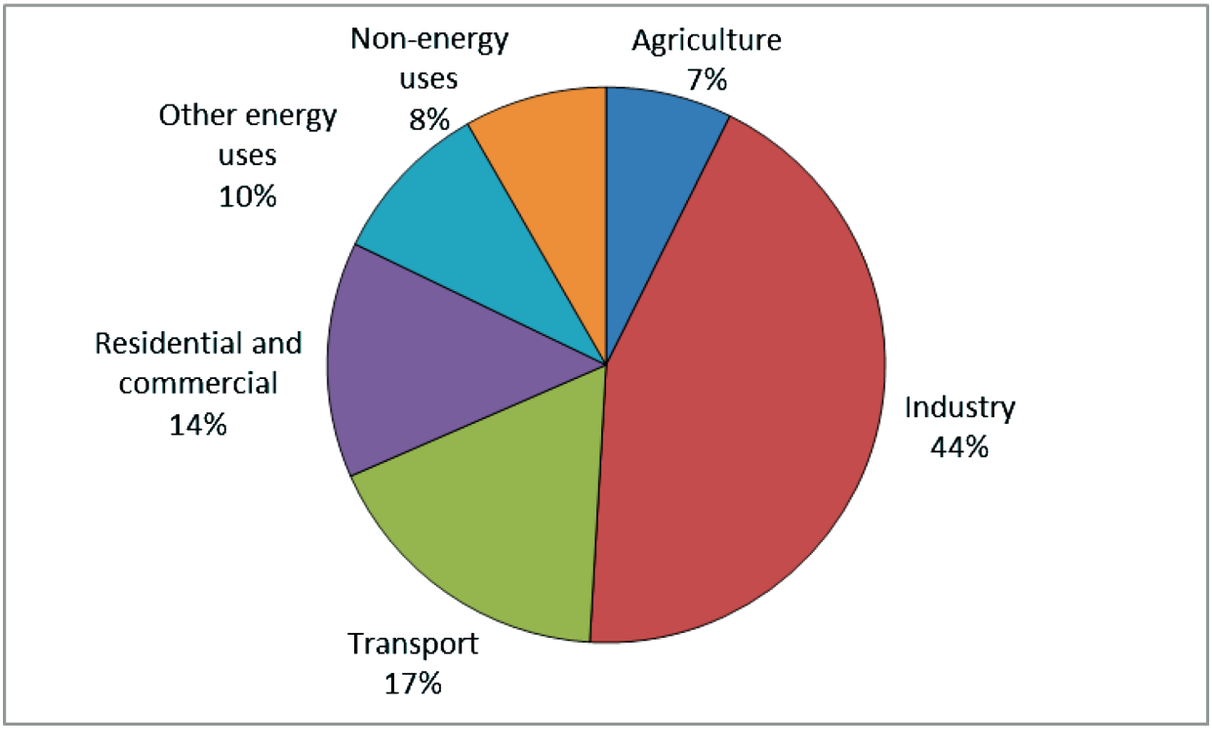


Figure 1.4 Sectorwise Energy Consumption
Source: TERI

Specific Energy Consumption (SEC) of the major industry sectors in India is much higher compared to global benchmarks (see Table 1.13). With ever increasing energy costs, it is more important to improve the energy efficiency of manufacturing processes in major industries and small enterprises.

Table 1.13 SEC in Selected Indian Industries against Global Benchmarks

Industry	Specific Energy Consumption (SEC) in GJ/ tonne	
	India	World
Iron & Steel	25.5 –34.2	16.5-18.5
Cement	3.0-3.4	2.9-3.0
Fertilizers(Urea)	27.2-28.5	24.0-25.8
Pulp & Paper	31.0-51.0	25.0-30.0
Chlor Alkali (Caustic Soda)	7.8-8.6	7.1-7.5
Aluminum	75.6-83.2	70.5-73.0
Sugar	0.7-0.9	0.6-0.7

Source: Planning Commission, India Report

However, the efficiencies of many processes in the Indian cement, steel and aluminium industries have improved over the past 15 years. Continuous improvements in enhancing energy efficiency have helped to lower the country's overall energy intensity to a certain extent. In the cement sector for example, the specific energy consumption of the most efficient plants is now comparable to the best in the world. However, much of the Indian industrial output is derived from small and medium industries operated with inefficient equipment, where it has been difficult to implement efficiency improvements.

Transport sector

The energy consumption of this sector is growing at a rapid rate of 16% per annum which is next only to China. This sector almost consumes around 40% of the petroleum products.

By the end of the projection period i.e. 2030, out of the total transport energy demand, road vehicles would account for 86% followed by aviation at 9%. Railways, marine and others are expected to consume 5%.

Residential, Commercial, Services and Agricultural sector

There exists a wide difference between the consumption pattern of the rural and urban households. The rural households depend upon biomass to meet 85% of their cooking needs, while the urban households meet 56% of their cooking needs through LPG. Almost 70% of the population in India is rural household, which accounts for only 42% of the demand for oil, gas and electricity. The use of electricity is growing rapidly in the residential sector. Of the total electricity demand in the domestic sector, 70% is used for lighting purpose while the balance 30% is accounted for refrigeration, air conditioning and other electrical gadgets.

The energy consumption especially for commercial and services activities is expected to grow rapidly due to high growth rate in commercial establishments, hotels, shopping malls, IT parks and hospitality industry.

Gradual shift to mechanized farming has lead to a steep rise in agricultural energy consumption, both electricity and diesel. The electricity consumption in agriculture sector has increased at a much faster rate compared to other sectors during the last four decades

1.9 Energy Needs of Growing Economy

Economic growth is desirable for developing countries, and energy is essential for economic growth. However, the relationship between economic growth and increased energy demand is not always a straightforward linear one.

Massive investment in energy sector is required to deliver a sustained GDP growth rate of 8.0% till the year 2031- 2032. The requirements of energy sector are:

- Growth in primary energy supply by 3-4 times over current consumption
- Increase in electricity installed capacity by 6-7 times
- Increase in annual coal requirement by nearly 3 times over the current demand

As far as electricity consumption is concerned, India has reached a level of about 917 kiloWatt hour (kWh) per person per year (2012-13) as shown in Table 1.14. The comparable figure for Japan is 7848, for China 3298, for USA 13,246, for UK 6206, for Canada 16,473 and the world average is 2430 (Source: World Bank). Thus, India's per capita electricity consumption is much less than that of many countries and much less than the World average

Table 1.14 Growth of Per Capita Consumption (kWh)

Particulars	2010-11	2011-12	2012-13
Per Capita Consumption (kWh)	819	884	917

Source: Growth of Electricity in India from 1947-2013: CEA Document

Requirement of coal, the dominant fuel in India's energy mix will need to expand to over 2 billion tonnes/annum based on domestic quality of coal given India's targeted GDP growth.

India's oil requirements also will increase at a significant rate. India already imports about 75% of its crude oil requirements which are likely to go up more than 90% in the near future as production in existing oil and gas fields are declining as a result of years of use.

The share of natural gas in the energy mix is expected to go upto 20-25% by the year 2030-32.

Nuclear power plant capacity targets as envisaged by the Department of Atomic Energy (DAE) are 20,000 MWe by 2020, 50,000 MWe by 2030 and 250,000 MWe of nuclear power by 2050.

1.10 Integrated Energy Policy

The power supply position prevailing in the country is characterized by persistent power shortages, unreliability and also high prices for industrial consumer. India depends on imported oil to an extent of about 75% and this raises energy security concerns.

Also consistency in policies governing each sector and consistency in pricing of different types of energy is lacking. There is a need for clarity in the direction which we must follow in aspects like energy security, addressing environmental concerns, energy conservation and Research and Development.

To achieve these objectives, Expert Committee has made a comprehensive review to make recommendations for integrated energy policy. The integrated energy policy is briefly covered in Chapter-2 of this book.

1.11 Energy Intensity on Purchasing Power Parity (PPP)

Energy intensity is the ratio between the gross inland consumption of energy and the gross domestic product (GDP) for a given calendar year. It measures the energy consumption of an economy and its overall energy efficiency.

The gross inland consumption of energy is a measure of the energy inputs to the economy, calculated by adding total domestic energy production plus energy imports minus energy exports plus net withdrawals from existing stocks.

The GDP figures are taken at constant prices to avoid the impact of the inflation, in relation to a base year (say 2000). Since gross inland consumption is measured in toe (tons of oil equivalent) and GDP in millions of US $, this ratio is expressed in toe per million US $.

$$EI = \frac{FC}{GDP}$$

Where:

EI = Energy intensity, national level, toe per million US $
FC = Total final consumption, national level, toe
GDP= Gross domestic product, million US $

A low energy intensity would indicate that the country has the right mix of industries sector wise. An economy dominated by heavy industrial production, for instance, is more likely to have higher energy intensity than the one where the service sector is dominant, even if the energy efficiencies of the two countries are identical. Likewise, a country that relies on trade to acquire (import) carbon-intensive goods will—when all other factors are equal—have lower energy intensity than the countries that manufacture the same goods for export.

Although, energy use generally increases as the economy grows, continuing improvement in the energy efficiency of the nation's economy and a shift to less energy-intensive activities are projected to keep the rate of energy consumption growth lower than the rate of GDP growth

What is Purchase Power Parity (PPP)?

An egg in India costs Rs.3/- whereas it costs 30 Yens/- (equivalent to Rs.15) in Japan. The PPP for an egg between Japan and India is 30 Yens to Rs.3 or 10 Yens to a rupee. In other words, for every rupee spent on egg in India, 10 Yens would have to be spent in Japan to obtain the same quality of egg.

Applying actual exchange rates of Yen to Rupee in this process would overestimate the GDP of Japan with high price levels relative to India with low price levels. The use of PPPs ensures that the GDP of all countries is valued at a uniform price level and thus reflects only differences in the actual volume of the economy. Adjustments are required to give a better picture than comparing gross domestic products (GDP) using market exchange rates.

A purchasing power parity (PPP) exchange rate equalizes the purchasing power of different currencies in their home countries for a given basket of goods. These special exchange rates are often used to compare the standards of living of two or more countries. In their simplest form, PPPs are price relatives that show the ratio of the prices in national currencies of the same good or service in different countries.

Simply, it means the purchasing power of country, after neutralizing the currency to global standards, thus giving a more correct picture of the country's purchasing power. PPP is a useful measure because, more often than not, the amount of goods a currency can purchase within two nations varies widely based on availability of goods, demand for the goods, and a number of other factors.

Taking into account PPP, the energy intensity is expressed as Energy Intensity (kgoe/US $PPP GDP).

1.12 Long Term Energy Scenario for India

Coal

Apart from meeting the energy needs of the industry, coal is the predominant energy source for power production in India accounting for about 60% of the installed capacity. Energy demand in India is expected to increase heavily over the next 10-15 years. Coal will continue to remain the dominant fuel in the Indian economy.

Despite significant increases in the total installed generation capacity during the last decade, the gap between the electricity supply and demand continues to increase. The resulting shortfall has had a negative impact on the industrial output and economic growth.

The coal production stood at around 551.71 Million tonnes by the end of 2013. Indian coal is typically of poor quality and as such requires beneficiation to improve the quality. As domestic coal production is very unlikely to cope with increasing demand, coal imports are expected to increase drastically in future to satisfy the industrial and power generation requirements.

Oil

India's demand for petroleum products rose from 97.7 million tonnes in 2001-02 to around 175.2 million tonnes by 2013. Domestic crude oil production was 37.788 million metric tonnes (MMT) for the year 2013-14.

India's self sufficiency in oil has consistently declined from 60% in the 1950s to 25% currently. Same is expected to go down to 8% by 2020. About 90% of India's total oil demand by 2020 would have to be met by imports.

Natural Gas

In keeping with the world wide trend, the demand for natural gas in India has been on the increase. The production of natural gas which was negligible at the time of independence is now at the level of 35.407 Billion Cubic Meters. To meet the future requirements of natural gas, trans-national gas pipelines are being planned.

While gas pipeline projects would yield results only in long term, immediate relief can come in the form of LNG. Import of LNG will require special terminals to handle them at the ports. The constructions of such terminals have already started and some of them have been commissioned. The world trade in LNG is around 150 Billion Cubic Metres (BCM). Geographically, India is strategically located and is flanked by large gas reserves on both East and West. India is located relatively near to four of top five countries in terms of proven gas reserves viz. Iran, Qatar, Saudi Arabia and Abu Dhabi. The large natural gas market of India is a major attraction to the LNG exporting countries. In order to encourage gas imports, Government has kept import of LNG under Open General License (OGL) and permitted 100% Foreign Direct Investment (FDI)

Electricity

With India already reeling under peak demand and energy shortage, increasing economic growth is expected to put heavy pressure on the power sector. For sustaining the current economic growth rate, the capacity will have to be doubled every 10 years.

Accelerated Power Development & Reforms Programme was introduced by the Ministry of Power in 2002-03 in order to improve the power reliability at the distribution level and to achieve commercial viability of State Electricity Boards. The strategies include technical, commercial, financial and IT interventions to achieve the following objectives

- Targets towards the commercial viability of the utilities by reducing their Aggregate Technical & Commercial (AT&C) losses to 15%
- Improvement in quality, supply and reliability of supply
- Improved revenue collection and customer satisfaction

APDRP was later restructured as R-APDRP, the focus of which is on actual, demonstrable performance in terms of loss reduction.

1.13 Electricity Pricing in India

In terms of purchasing power parity, power tariffs in India for industries and commercial establishments are among the highest in the world. The average tariff on PPP basis in India is 30.8 cents/kWh, while it is 7.7 in US, 15.3 in Japan and 20.6 in China.

Consumer prices for electricity are currently set by State Electricity Regulatory Commissions on cost plus basis. Power tariffs are structured on the basis of industrial and commercial users cross subsidizing agricultural and domestic power consumption.

Electricity tariffs in India are structured in a relatively simple manner. While high tension consumers are charged based on both demand (kVA) and energy (kWh), the low-tension (LT) consumer pays only for the energy consumed (kWh) as per tariff system in most of the distribution companies. The price per kWh varies significantly across States as well as customer segments within a State.

The agricultural sector is supplied un-metered power in almost all states and the farmers pay a highly subsidized lump sum amount based on the declared horse power of their pumps. This leads to a zero marginal cost of power which promotes inefficient use and over exploitation of ground water. The domestic sector also has a range of subsidies based on the level of consumption including heavily subsidised power for the poorest segment wherein households pay a low lump sum monthly charge. With the rising cost of supply, the burden of these cross-subsidies has increased and is disproportionately loaded on the paying industrial, commercial and large household consumers.

Introduction of Availability Based Tariffs (ABT) and unscheduled interchange charges for power, introduced in 2003 for inter-state sale of power, have reduced voltage and frequency fluctuations.

What is ABT?

- It is a performance-based tariff system for the supply of electricity by generators owned and controlled by the central government
- It is also a new system of scheduling and dispatch, which requires both generators and beneficiaries to commit to day-ahead schedules.
- It is a system of rewards and penalties seeking to enforce day ahead pre-committed schedules, though variations are permitted if notified one and half hours in advance.
- The order emphasises prompt payment of dues. Non-payment of prescribed charges will be liable for appropriate action.

1.14 Energy Security

The basic aim of energy security for a nation is to reduce its dependency on the imported energy sources for its economic growth. Energy security is defined as **"The continuous availability of energy in varied forms in sufficient quantities at reasonable prices".**

World Energy Assessment (UNDP 1999)

Energy security is a serious concern because India's energy needs are growing with rising income levels and a fast growing population. The dependence on imported energy is also increasing rapidly due to increasing energy needs. A special concern is that the import of oil is about 75% of total oil consumption. The domestic oil wells are all over 30 years old and the yield from these wells have started reducing. Oil demand is rising at a rate of about 5% every year leading to huge oil import bills. By 2020, it is projected that our oil imports would exceed 90% of the total consumption if the economic growth continues at the same pace as now.

Any disruption in energy supplies would be harmful to the country's economic growth, human survival and well being. For example, disruption in oil supply or increase in price of oil will force the farmers to reduce the use of pumps and tractors and this will lead to lower agricultural output which in turn may lead to lower employment.

India is dependent on Middle East- a region prone to disturbances and disruptions of oil supplies- for most of our oil imports. This calls for diversification of sources of oil imports. The need to deal with oil price fluctuations also necessitates measures to be taken to reduce the oil dependence of the economy, possibly through fiscal measures to reduce demand, and by developing alternatives to oil, such as natural gas and renewable energy.

Poor coal quality and high prices of domestic coal will drive the increase in coal imports from present level of 25%. The imports of gas and LNG (liquefied natural gas) are likely to increase in the coming years. Thus the energy import dependence implies vulnerability to external price shocks and supply fluctuations, which in turn threaten the energy security of the country.

Some of the strategies that can be used to meet future energy requirements include:

- Reducing energy requirements
    - Improving the efficiency of extraction of fossil fuels
    - Improving fuel efficiency of new coal-fired power plants by adopting new technology (i.e. super critical pulverized fuel fired boilers)
    - Adopting energy efficiency and demand side management
    - Promotion of public transport / mass transport (e.g. metro rail, light rail, monorail etc.) in urban areas
    - Developing renewable energy sources especially solar and wind
- Substituting imported oil/gas with domestic alternatives
    - Ethanol / Biodiesl as substitute for petrol / diesel
    - Biomass gasification for heat or power as alternative to gas / coal
    - Coal-to-oil technology as done in South Africa

- Diversifying energy supply sources
  - Mix of fuel comprising of coal, gas, nuclear, hydro and renewables with no dependence on any particular fuel
  - Sourcing oil / LNG from different countries
  - Importing gas through pipelines passing through countries who also benefit
- Expanding energy resource and developing alternative energy sources
  - Improved Oil Recovery (IOR) and Enhanced Oil Recovery (EOR) for improving exploitation of reserves
  - Recovery of oil and gas from abandoned or marginal fields
  - In-situ coal gasification
  - Capturing Coal Bed Methane (CBM) which escapes from coal seams during mining
  - Conversion of coal to oil
  - Gas to Liquid (GTL)
  - Stepping up exploration to find new reserves (only one-third of oil bearing area explored so far)
  - Equity oil, gas, coal from other countries
  - Setting up energy intensive units (i.e. fertilizer plants) abroad
  - New domestic sources (nuclear –fast breeder reactor, thorium reactors, gas hydrates etc.)
  - Promoting Community Biogas Plants
  - Energy plantations

1.15 Energy Conservation and its Importance

Coal and other fossil fuels, have taken hundreds of millions of years to form, are likely to deplete soon. In the last two hundred years, we have consumed 60% of all resources. For sustainable development, we need to adopt energy efficiency measures.

Today, 85% of India's primary energy comes from non-renewable and fossil sources (coal, oil, etc.). These reserves are continually diminishing with increasing consumption and will not exist for future generations (see Figure 1.5).

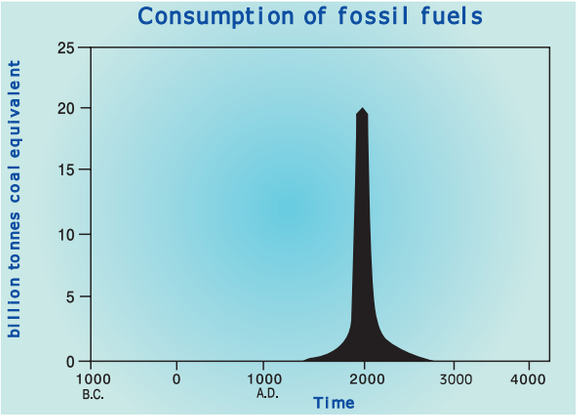


Figure 1.5 Consumption of Fossil Fuels

What is Energy Conservation?

Energy Conservation and Energy Efficiency are separate, but related concepts. Energy conservation is achieved when growth of energy consumption is reduced in physical terms. Energy Conservation can, therefore, is the result of several processes or developments, such as productivity increase or technological progress. On the other hand Energy efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without affecting output, consumption or comfort levels. Promotion of energy efficiency will contribute to energy conservation and is therefore an integral part of energy conservation promotional policies.

Energy efficiency is often viewed as a resource option like coal, oil or natural gas. It provides additional economic value by preserving the resource base and reducing pollution. For example, replacing Incandescent lamps with LED's means will require 1/8th of the energy to light a room. Pollution levels also reduce by the same amount (refer Figure 1.6).

Nature sets some basic limits on how efficiently energy can be used, but in most cases our products and manufacturing processes are still a long way from operating at this theoretical limit. Very simply, energy efficiency means using less energy to perform the same function.

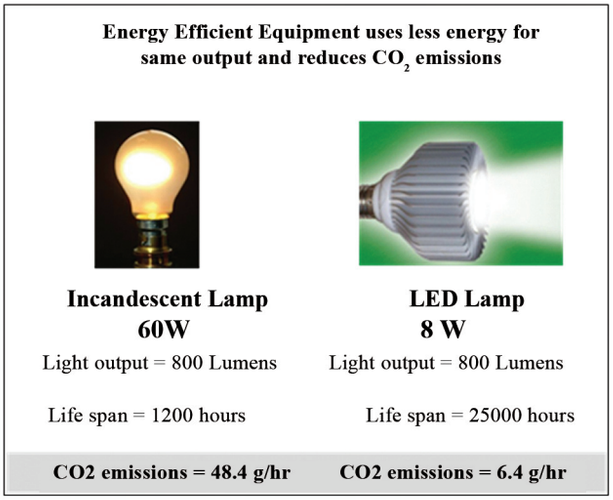


Figure 1.6 Energy Efficient Equipment

Although, energy efficiency has been in practice ever since the first oil crisis in 1973, it has today assumed even more importance because of being the most cost-effective and reliable means of mitigating the global climatic change. Recognition of that potential has led to high expectations for the reduction of future CO_2 emissions through more energy efficiency improvements than that achieved in the past. The industrial sector accounts for about 41 per cent of global primary energy demand and approximately the same share of CO_2 emissions. The benefits of Energy conservation for various players are given in Figure 1.7.

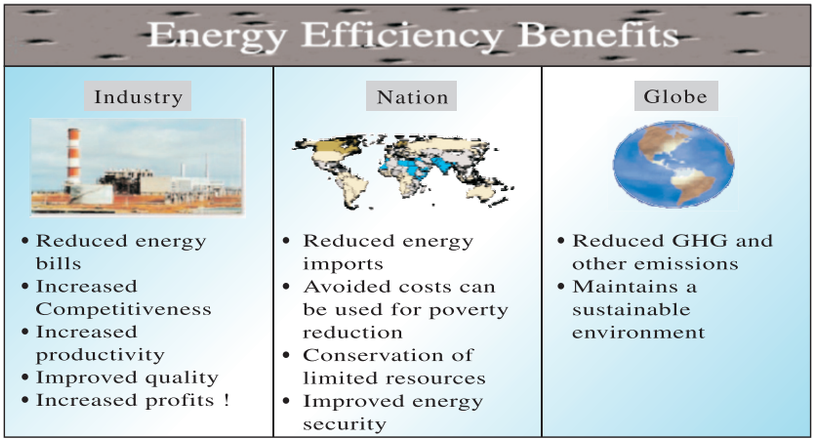


Figure 1.7 Energy Efficiency Benefits

QUESTIONS	
Objective Type Questions	
1.	The Government of India levies Clean Energy Cess on which of the following: a) Electricity b) Coal c) Diesel d) Biodiesel
2.	One tonne of oil equivalent is a) 10,000 kcal b) 1000 kcal c) 1000 kg of oil d) 10 Mcal
3	Which of the following is not a national mission under the Prime Minister's National Action Plan on Climatic Change a) National solar mission b) National mission for enhanced energy efficiency c) National mission on CFC alternatives d) National mission for green India
4	The country that accounts for largest energy consumption is a) USA b) Russia c) China d) India
5.	Coal in our planet is expected to last for about a) 45 years b) 65 years c) 200 years d) 113 years
6.	The major source of electrical power generation in India is a) thermal b) hydel c) nuclear d) wind
7.	Which of the following with respect to fossil fuels is true? a) R/P ratio is a constant once established b) R/P varies every year with only changes in production c) R/P ratio varies with only changes in reserves d) R/P ratio varies every year with changes in both production and reserves
8.	Nuclear energy development in India is constrained by a) low % of Uranium in the ore b) inadequate supply of Uranium c) constraints in import of Uranium d) all of the above
9.	Availability based tariff is applicable to a) oil b) coal c) natural gas d) electricity
10.	Energy intensity is the ratio of a) fuel consumption / GDP b) GDP/fuel consumption c) GDP/energy consumption d) energy consumption/GDP
Short Type Questions	
S-1	Write a short description about Availability Based Tariff (ABT)
S-2	Briefly explain 'Renewable Purchase Obligation (RPO) and means by which this requirement can be met?

S-3	Give a short description about primary and secondary energy with examples
S-4	Covert the following into tonnes of oil equivalent 10,000 kg of coal with a calorific value of 4000 kcal/kg 10 lac kWh
S-5	What is meant by PPP?
Long Type Questions	
L-1	Explain the difference between energy conservation and energy efficiency with a suitable example
L-2	List five strategic measures for meeting energy security of a country.

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   www.bp.com/centres/energy

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Chapter 2

Energy Conservation Act, 2001 and Related Policies

Learning Objectives

In this chapter you will learn about

- Salient features of Energy Conservation Act 2001
- State Designated Agencies
- Schemes of Bureau of Energy Efficiency (BEE) – ECBC, S & L, DSM, BLY, SMEs
- Designated consumers
- Electricity Act 2003
- Integrated energy policy
- National action plan on climate change

2. ENERGY CONSERVATION ACT-2001 AND RELATED POLICIES

Energy conservation Act-2001 and its features, Notification under the Act Schemes of Bureau of Energy Efficiency (BEE)- ECBC, S&L, DSM, BLY, SME's, Designated Agencies, Electricity Act 2003, Integrated Energy Policy, National Action plan on Climate Change

2.1 Introduction

Energy Conservation Act (EC Act) was enacted by the Government of India in 2001 to provide legal framework and institutional arrangements for enhancing energy efficiency. This Act led to the creation of Bureau of Energy Efficiency (BEE) as the nodal agency at the center and State Designated Agencies (SDAs) at the State level to implement the provisions of the Act. The Central Government, State Government and Bureau of Energy Efficiency have major roles to play in implementation of the Act. The Mission of BEE is to develop policy and strategies based on self-regulation and market principles with the goal of reducing energy intensity of the Indian economy. This will be achieved with active participation of all stakeholders, resulting in rapid and sustained adoption of energy efficiency in all sectors.

2.2 Salient Features of the Energy Conservation Act, 2001 (Amended in 2010)

The Act empowers the Central and State Governments to facilitate and enforce efficient use of energy and its conservation, notify energy-intensive industries, establishments and commercial buildings as designated consumers and prescribe energy consumption norms and standards for designated consumers. The Act was amended in 2010.

The Amendment expanded the scope of energy conservation norms for buildings and tightened the applicability of energy efficiency norms for appliances and equipment. It provided a framework within which savings on energy use can be traded between those industries who are energy efficient and those whose consumption of energy is more than the maximum set by the government. The amendment increased penalties for non-compliance and provided for establishment of appellate tribunal for energy conservation to hear appeals against the orders of the adjudicating officer or the Central Government or the State Government or any other authority under the Energy Conservation Act.

The excerpts of relevant sections of Energy Conservation Act are reproduced below for the benefit of Energy Managers and Energy Auditors. However the full text of the act is available in BEE website.

Key Definitions as Outlined in the Act

Building: "building" means any structure or erection or part of structure or erection after the rules relating to energy conservation building codes have been notified (under clause (p) of section 14 and clause (a) of section 15) and includes any existing structure or erection or part of structure or erection,

which is having a connected load of 100 Kilowatt (kW) or contract demand of 120 Kilo- volt Ampere (kVA) and above and is used or intended to be used for commercial purposes.

Designated agency: Designated agency means an agency which coordinates, regulates and enforce provisions of this act within a State.

Designated consumer: Designated consumer means any user or class of users of energy in a energy intensive industries and other establishments specified in the Schedule as designated consumer.

Energy: Energy means any form of energy derived from fossil fuels, nuclear substances or materials, hydro-electricity and includes electrical energy or electricity generated from renewable sources of energy or biomass connected to the grid.

Energy audit: Energy audit means the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption.

Energy conservation building codes: It means the norms and standards of energy consumption expressed in terms of per square meter of the area and wherein energy is used and includes location of the building.

Energy consumption standards: It means norms for process and energy consumption standards (specified under clause (a) of section 14).

Energy savings certificate : "Energy savings certificate" means any energy savings certificate issued to the designated consumers (under sub-section (1) of section 14A).

Equipment or appliance: It means any equipment or appliance which consumes, generates, transmits or supplies energy and includes any device that consumes any form of energy and produces a desired work.

CHAPTER IV of EC Act

13. Powers and Functions of Bureau

13. (1) The Bureau shall, effectively co-ordinate with designated consumers, designated agencies and other agencies, recognize and utilise the existing resources and infrastructure, in performing the functions assigned to it by or under this Act.

(2) The Bureau may perform such functions and exercise such powers as may be assigned to it by or under this Act and in particular, such functions and powers include the function and power to -

(a) recommend to the Central Government the norms for processes and energy consumption standards required to be notified under section 14A;

(aa) recommend to the Central Government for issuing of the energy savings certificate

(b) recommend to the Central Government on display label on equipment or on appliances and manner of display under clause (d) of section 14;

(c) recommend to the Central Government for notifying any user or class of users of energy as a designated consumer under clause (e) of section 14;

(d) take suitable steps to prescribe guidelines for energy conservation building codes under clause (p) of section 14.

(e) take all measures necessary to create awareness and disseminate information for efficient use of energy and its conservation;

(f) arrange and organize training of personnel and specialists in the techniques for efficient use of energy and its conservation;

(g) strengthen consultancy services in the field of energy conservation;

(h) promote research and development in the field of energy conservation;

(i) develop testing and certification procedure and promote testing facilities for certification and testing for energy consumption of equipment and appliances;

(j) formulate and facilitate implementation of pilot projects and demonstration projects for promotion of efficient use of energy and its conservation;

(k) promote use of energy efficient processes, equipment, devices and systems;

(l) promote innovative financing of energy efficiency projects;

(m) give financial assistance to institutions for promoting efficient use of energy and its conservation;

(n) levy fee for services provided for promoting efficient use of energy and its conservation;

(o) maintain a list of accredited energy auditors as may be specified by regulations;

(p) specify, by regulations, the qualifications, criteria and conditions subject to which a person may be accredited as an energy auditor and the procedure for such accreditation;

(q) specify, by regulations, the manner and intervals of time in which the energy audit shall be conducted;

(r) specify, by regulations, certification procedures for energy managers and energy auditors to be designated or appointed by designated consumers;

(s) prepare educational curriculum on efficient use of energy and its conservation for educational institutions, boards, universities or autonomous bodies and coordinate with them for inclusion of such curriculum in their syllabus;

(sa) conduct examination for capacity building and strengthening of services in the field of energy conservation including certification of energy managers and energy auditors.

(t) implement international co-operation programmes relating to efficient use of energy and its conservation as may be assigned to it by the Central Government.

CHAPTER V of EC Act

Power of Central Government to Facilitate and Enforce Efficient Use of Energy and its Conservation

14. Central Government may, by notification, in consultation with the Bureau, -

(a) specify the norms for processes and energy consumption standards for any equipment, appliances which consumes, generates, transmits or supplies energy

(b) specify equipment or appliance or class of equipments or appliances, as the case may be, for the purposes of this Act;

(c) prohibit manufacture or sale or purchase or import of equipment or appliance specified under clause(b) unless such equipment or appliances conforms to energy consumption standards;

– Provided that no notification prohibiting manufacture or sale or purchase or import or equipment or appliance shall be issued within a period of six months from the date of notification;

– Provided further that the Central Government may, having regard to the market share and the technological development having impact on equipment or appliance, and for reasons to be recorded in writing, extend the said period of six months referred to in the first proviso by a further period not exceeding six months;

(d) direct display of such particulars on label on equipment or on appliance specified and in such manner as may be specified by regulations;

(e) specify, having regarding to the intensity or quantity of energy consumed and the amount of investment required for switching over to energy efficient equipments and capacity or industry to invest in it and availability of the energy efficient machinery and equipment required by the industry, any user or class of users of energy in the energy intensive industries and other establishment as a designated consumer;

(f) alter the list of Energy Intensive Industries specified in the Schedule;

(g) establish and prescribe such energy consumption norms and standards for designated consumers as it may consider necessary:

– Provided that Central Government may prescribe different norms and standards for different designated consumers having regard to such factors as may be prescribed;

(h) direct, having regard to quantity of energy consumed or the norms and standards of energy consumption the energy intensive industries specified in the Schedule to get energy audit conducted by an accredited energy auditor in such manner and intervals of time as may be specified by regulations;

(i) direct, if considered necessary for efficient use of energy and its conservation, any designated consumer to get energy audit conducted by an accredited energy auditor;

(j) specify the matters to be included for the purposes of inspection

(k) direct any designated consumer to furnish to the designated agency, in such form and manner and within such period, as may be prescribed, the information with regard to the energy consumed and action taken on the recommendation of the accredited energy auditor;

(l) direct any designated consumer to designate or appoint energy manger in charge of activities for efficient use of energy and its conservation and submit a report, in the form and manner as may be prescribed, on the status of energy consumption at the end of the every financial year to designated agency;

(m) prescribe minimum qualification for energy managers to be designated or appointed under clause *(l)*;

(n) direct every designated consumer to comply with energy consumption norms and standards;

(o) direct any designated consumer, who does not fulfill the energy consumption norms and standards prescribed under clause (g), to prepare a scheme for efficient use of energy and its conservation and implement such scheme keeping in view of the economic viability of the investment in such form and manner as may be prescribed;

(p) prescribe energy conservation building codes for efficient use of energy and its conservation in the building or building complex;

(q) amend the energy conservation building codes to suit the regional and local climatic conditions;

(r) direct every owner or occupier of the building or building complex, being a designated consumer to comply with the provisions of energy conservation building codes for efficient use of energy and its conservation;

(s) direct, any designated consumer referred to in clause *(r)*, if considered necessary, for efficient use of energy and its conservation in his building to get energy audit conducted in respect of such building by an accredited energy auditor in such manner and intervals of time as may be specified by regulations;

(t) take all measures necessary to create awareness and disseminate information for efficient use of energy and its conservation;

(u) arrange and organise training of personnel and specialists in the techniques for efficient use of energy and its conservation;

(v) take steps to encourage preferential treatment for use of energy efficient equipment or appliances:

14A (1) The Central Government may issue the energy savings certificate to the designated consumer whose energy consumption is less than the prescribed norms and standards in accordance with the procedure as may be prescribed.

(2) The designated consumer whose energy consumption is more than the prescribed norms and standards shall be entitled to purchase the energy savings certificate to comply with the prescribed norms and standards.

14B The Central Government may, in consultation with the Bureau, prescribe the value of per metric ton of oil equivalent of energy consumed for the purposes of this Act.

CHAPTER VI of EC ACT

Power of State Government to facilitate and Enforce Efficient Use of Energy and its Conservation

15. The State Government may, by notification, in consultation with the Bureau -

(a) amend the energy conservation building codes to suit the regional and local climatic conditions and may, by rules made by it, specify and notify energy conservation building codes with respect to use of energy in the buildings;

(b) direct every owner or occupier of a building or building complex being a designated consumer to comply with the provisions of the energy conservation building codes;

(c) direct, if considered necessary for efficient use of energy and its conservation, any designated consumer to get energy audit conducted by an accredited energy auditor in such manner and at such intervals of time as may be specified by regulations;

(d) designate any agency as designated agency to coordinate, regulate and enforce provisions of this Act within the State;

(e) take all measures necessary to create awareness and disseminate information for efficient use of energy and its conservation;

(f) arrange and organise training of personnel and specialists in the techniques for efficient use of energy and its conservation;

(g) take steps to encourage preferential treatment for use of energy efficient equipment or appliances;

(h) direct, any designated consumer to furnish to the designated agency, in such form and manner and within such period as may be specified by rules made by it, information with regard to the energy consumed by such consumer;

(i) specify the matters to be included for the purposes of inspection..

Establishment of Fund by State Government

16. (1) The State Government shall constitute a Fund to be called the State Energy Conservation Fund for the purposes of promotion of efficient use of energy and its conservation within the State.

(2) To the Fund shall be credited all grants and loans that may be made by the State Government or, Central Government or any other organization or individual for the purposes of this Act.

(3) The Fund shall be applied for meeting the expenses incurred for implementing the provisions of this Act.

(4) The Fund created shall be administered by such persons or any authority and in such manner as may be specified in the rules made by the State Government.

Power of Central Government or State Government to issue directions

18. The Central Government or the State Government may, in the exercise of its powers and performance of its functions under this Act and for efficient use of energy and its conservation, issue such directions in writing as it deems fit for the purposes of this Act to any person, officer, authority or any designated consumer and such person, officer or authority or any designated consumer shall be bound to comply with such directions.

Explanation – For the avoidance of doubts, it is hereby declared that the power to issue directions under this section includes the power to direct –

(a) Regulation of norms for process and energy consumption standards in any industry or building or building complex; or

(b) Regulation of the energy consumption standards for equipment and appliances.

CHAPTER VIII of EC Act

PENALTIES AND ADJUDICATION

26. Penalty

(1) If any person fails to comply with the provisions of clause (c) or clause (d) or clause (h) or clause (i) or clause (k) or clause (l) [xxx] or clause (r) or clause (s) of section 14 or clause (b) or clause (c) or clause (h) of section 15, he shall be liable to a penalty which shall not exceed ten lakh rupees for each such failure and, in the case of continuing failure, with an additional penalty which may extend to ten thousand rupees for every day during which such failure continues:

PROVIDED that no person shall be liable to pay penalty within five years from the date of commencement of this Act.

(1A) If any person fails to comply with the provisions of clause (n) of section 14, he shall be liable to a penalty which shall not exceed ten lakh rupees and, in the case of continuing failure, with an additional penalty which shall not be less than the price of every metric ton of oil equivalent of energy, prescribed under this Act, that is in excess of the prescribed norms.

(2) Any amount payable under this section, if not paid, may be recovered as if it were an arrear of land revenue.

Role of State Designated Agencies

As per Energy Conservation Act 2001, State Governments have been empowered to designate agencies (State Designated Agency, i.e. SDA) in consultation with Bureau of Energy Efficiency. Designated Agencies will have the responsibility to implement the Act within the State.

Responsibilities

- Spread awareness on EC Act
- Undertake voluntary initiatives to promote energy conservation
- Liaison and coordinate with BEE, State Government Departments dealing with energy, industry, planning, regulators, consumer affairs, municipal bodies etc.
- Capacity building of staff employed
- Launch and maintain state specific website addressing the voluntary and mandatory provisions of EC Act
- Undertake energy conservation awareness program for consumers, industrial & commercial sector, school children, farmers etc.
- Arrange interactive meets between energy managers, energy auditors, designated consumers and other experts

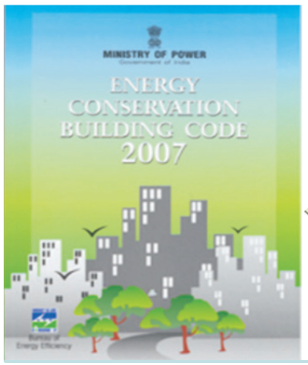
Duties

- Prepare a list of designated consumers
- Compile information received from designated consumers through annual statements on energy consumption, energy audit reports, and action taken on the report of energy audit
- Prepare a state and sectoral energy data base and provide the feed back to designated consumers
- Take all measures necessary to create awareness and disseminate information for efficient use of energy and its conservation
- Arrange and organize training of personnel and specialists in the techniques for efficient use of energy and its conservation
- Take steps to encourage preferential treatment for use of energy efficient equipment or appliances
- Appoint or designate inspecting officer with specified powers as necessary for the purpose of ensuring compliance with energy consumption standards
- Assist State Government in the preparation of Rules under Section 57 of the Energy Conservation Act.
- Establish Energy Conservation Fund for the purposes of promotion of efficient use of energy and its conservation within the State.

2.3 Schemes of BEE under the Energy Conservation Act-2001

- Energy Conservation Building Codes (ECBC)
- Standards and Labeling (S & L)
- Demand Side Management (DSM)
- Bachat Lamp Yojana (BLY)
- Promoting Energy Efficiency in Small and Medium Enterprises (SMEs)
- Designated Consumers
- Certification of energy auditors and energy managers

2.3.1 Energy Conservation Building Codes (ECBC)



Energy Conservation Building Codes (ECBC) was developed to deal with rapidly increasing energy consumption in commercial buildings. ECBC sets minimum energy efficiency standards for design and construction of commercial buildings.

ECBC encourages energy efficient design or retrofit of buildings so that

- Building funciton, comfort, health and the productivity of the occupants is considered
- Life cycle costs (i.e. construction and energy cost are minimized)

ECBC defined the norms of energy requirement per sq.metre of area and takes into consideration the climatic region of the country, where the building is located. The owners or occupiers have to comply with energy consumption norms and standards and / or to prepare and implement schemes for its efficient use and conservation. Central Government can prescribe energy conservation building codes and direct owners/ occupiers to comply with them. State Governments can modify the codes to suit regional and local climatic conditions.

For details on energy conservation in buildings and ECBC, reader is advised to refer Book-3, Chapter 10.

2.3.2 Standards and Labeling (S&L)

There is a wide variation in energy consumption of similar products by various manufacturers. Also information on energy consumption is often not easily available. This leads to continued manufacture and purchase of inefficient equipment and appliances.

The objectives of Standards & Labeling Program is to provide the consumer an informed choice about the energy saving and thereby the cost saving potential of the marketed household and other equipment. This is expected to impact the energy savings in the medium and long run while at the same time it will position domestic industry to compete in such markets where norms for energy efficiency are mandatory.

The main provision of EC act on Standards and Labeling are:

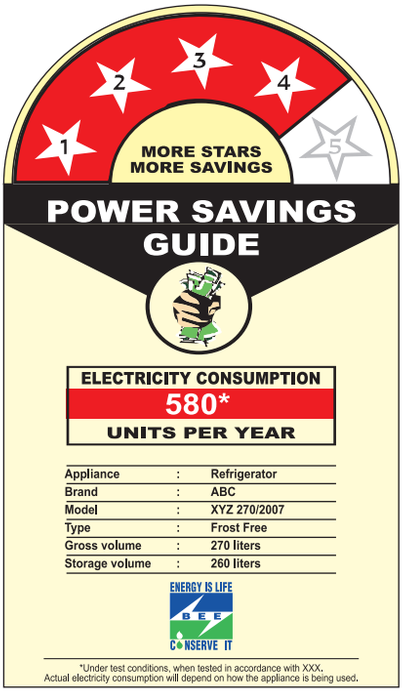
- Recommend to the Central Government, the norms for processes & energy consumption
- standards for any equipment which consumes, generates, transmits or supplies energy.

- Recommend to the Central Government the particulars required to be displayed on label of equipment or an appliances and manner of their display.
- Prevent manufacture, sale and import of such equipment, which does not comply with the notified standards.
- Promote use of energy efficient processes, equipment, devices and systems;
- Spread information on the benefits to consumers

Standard: Energy-efficiency standards are procedures and regulations prescribing the energy performance of manufactured/ commercially sold products sometimes prohibiting the sale of products that are less efficient than a minimum level. The term "standards" commonly encompasses two possible meanings:

a) well-defined test protocols (or test procedures) to obtain a sufficiently accurate estimate of the energy performance of a product, or at least a relative ranking of its energy performance compared to that of other models; and

b) target limits on energy performance (usually maximum use or minimum efficiency) based on a specified test protocol.



Labels: Energy-efficiency labels are informative labels affixed to manufactured products to describe the product's energy performance (usually in the form of energy use, efficiency). These labels give consumers the data necessary to make informed purchases. Mainly there are two types of labels namely,

a) Comparative label: allow consumers to compare efficiency of all the models of a product in order to make an informed choice. It shows the relative energy use of a product compared to other models available in the market.

b) Endorsement label: define a group of products as efficient when they meet minimum energy performance criteria specified in the respective product schedule/regulation/statutory order.

Minimum Energy Performance Standards (MEPS): MEPS prescribe minimum efficiencies (or maximum energy consumption) that manufacturers must achieve in each product, specifying the energy performance(or output) but not the technology or design details of the product. The MEPS will be reviewed and upgraded periodically to enhance & ensure the availability of energy efficiency product in the market.

Star Ratings: A ranking system based on energy efficiency of an appliance declared by manufacturer. Depending upon the performance of an appliance, they are rated on a scale of star 1 to star 5. The number of stars depends on the highest pre-set threshold for energy performance that the appliance is able to meet. Therefore, Star 1 is the least energy efficient (and hence the least money saved) and star 5 is the most energy efficient (and hence more money saved).

Label period: The validity period of the energy efficiency label under the energy consumption standard specified by the Central Government under clause (a) of Section 14 and in case the end period of the energy efficiency label is not specified, it shall be deemed to be valid until a new energy efficiency level is announced by the Central Government.

Appliances/equipment covered under S&L program:

In the 11th plan, S&L Programme has been expanded to 18 equipment out of which 4 equipment are introduced for mandatory S&L scheme from 7th January 2010. The equipment under the mandatory labeling program are:

1. Household Frost Free Refrigerators
2. Room Air Conditioners
3. Tubular Fluorescent Lamps
4. Distribution Transformers (up to 200 KVA)

Frost-free Refrigerator	TFL	AC	Distribution Transformer

The following equipment have been introduced under voluntary labeling scheme:

1. Direct Cool Refrigerators
2. Induction Motors
3. Ceiling Fans
4. Agricultural pump Sets
5. Color Televisions
6. Electric Water Geysers
7. Laptop & Notebook
8. Office equipments
9. LPG Stoves
10. Cassette/Floor standing ACs
11. Solid State Inverters
12. Diesel Generators
13. Ballast
14. Diesel Engine driven moonset pumps for agricultural purpose
15. Washing Machine

(Note: More Details are available at www.beestarlabel.com)

Example: Energy & Cost Savings estimation for Star rated appliance

Comparison of Star Rated Refrigerator with Non Star rated Refrigerator (220 Liters)

S No	Parameter	Star Rated Refrigerator	Non Star Rated Refrigerator
1.	Cost	Rs 17,000/-	Rs 10,000/-
2.	Star level	5 star	No star
3.	Annual Electricity consumption	204 Units	520 Units
4.	Annual Electricity savings	316 Units	
5.	Annual Electricity Cost (@Rs 5/ Unit)	Rs 1020/-	Rs 2600/-
6.	Annual Money Savings	Rs 1580/-	
7.	Payback Period	1-1.5Years	

Note: The cost of refrigerators & electricity consumption non star refrigerator is an assumption for savings estimation. The actual value may vary.

2.3.3 Demand Side Management (DSM)

Demand Side Management (DSM) means managing of the demand for power, by utilities / Distribution companies, among some or all its customers to meet current or future needs. DSM programs result in energy and / or demand reduction. For example, under this process, the demand can be shifted from peak to off peak hours thereby reducing the need for buying expensive imported power during peak hours. DSM also enables end-users to better manage their load curve and thus improves the profitability. Potential energy saving through DSM is treated same as new additions on the supply side in MWs. DSM can reduce the capital needs for power capacity expansion.

Pilot study undertaken by BEE has indicated energy saving potential of 40% by replacement of inefficient pumps with Star rated pump sets. BEE has prepared an Agricultural DSM (Ag. DSM) programme in which pump set efficiency upgradation could be carried out by an Energy Service Company (ESCOs) or distribution company. The implementation for replacement of inefficient pumps with Star rated pump sets will be done through the ESCO/Utility who would invest in energy efficiency measures on a rural pump set feeder on which supply quality enhancements (such as feeder segregation & High Voltage Direct Supply (HVDS) have already been carried out.

Almost all municipal bodies depend on government support to meet their development and operating expenses. Government of India, through the Bureau of Energy Efficiency has initiated a municipality DSM programme to cover 175 municipalities in the country by conducting investment grade energy audits and preparation of detailed project reports. Energy Service Companies are being encouraged to take up the implementation of the programme with the help of financial institutions.

2.3.4 Bachat Lamp Yojana (BLY)

The "Bachat Lamp Yojana", which literally means "Save Lamp Scheme", aims at the large scale replacement of inefficient incandescent bulbs in households by Compact Fluorescent Lamps (CFLs). It seeks to provide CFLs to households at the price similar to that of incandescent bulbs and plans to use the Clean Development Mechanism (CDM) to recover the cost difference between the market price of the CFLs and the price at which they are sold to households.

The Bachat Lamp Yojana is designed as a public-private partnership between the Government of India, Investors/ private sector CFL suppliers and State level Electricity Distribution Companies (DISCOMs). The CFL suppliers would sell high quality CFLs to households at a price of Rs. 15 per CFL within a designated project area in a DISCOM region of operation.

The CFL supplier/Investor would be selected by the DISCOM from a list of CFL suppliers empanelled by BEE. Under the scheme 60 Watt and 100 Watt incandescent Lamps would be replaced with 11- 15 Watt and 20 - 25 Watt CFLs respectively. It is estimated that 80% energy savings can be achieved without affecting lumen intensity.

Till date, 50 small scale BLY projects from various parts of India have been included in this registered umbrella framework and 43 projects have been implemented. As a result, about 29.5 million CFLs have been distributed during XI plan period.

2.3.5 Promoting Energy Efficiency in Small and Medium Enterprises (SMEs)

Energy Efficiency in the SME sector assumes importance because of the prevailing high costs of energy and supply related concerns. It will be useful to build their energy efficiency awareness by funding/subsidizing need based studies in large number of units in the SMEs and giving energy conservation recommendations including technology upgradation opportunities. It is envisaged that such interventions supported by diagnostic studies and pilot projects at cluster level focusing on energy/ resource efficiency, energy conservation and technology upgradation would be helpful in addressing the cluster specific problems and enhancing energy efficiency in SMEs.

Bureau of Energy Efficiency (BEE) is implementing a program (BEE's SME Program) to improve the energy performance in selected SME clusters. The objective of the program is to accelerate the adoption of energy efficient technologies and practices in the chosen SME clusters through knowledge sharing, capacity building and development of innovative financing mechanisms. The project is envisaged to be driven by market based mechanism that include facilitating knowledge creation at the local level, capacity building of local service providers and technology providers and thereafter facilitation of energy efficiency measures implementation through collateral funding by lead banks. The project is thus entirely market driven. Examples of clusters chosen for this project are Ahmedabad (chemicals), Surat (textiles), Warangal (rice milling) etc.

2.3.6 Designated Consumers (DC)

The Central Government has notified the following 9 energy intensive industries as designated consumers under The EC Act 2001:

No.	Industry	Energy consumption
1.	Thermal Power Stations	30,000 metric tonne of oil equivalent (MTOE) per year and above
2.	Fertilizer	30,000 metric tonne of oil equivalent (MTOE) per year and above
3.	Cement	30,000 metric tonne of oil equivalent (MTOE) pe*r year and above
4.	Iron & Steel	30,000 metric tonne of oil equivalent (MTOE) per year and above
5.	Chlor-Alkali	12,000 metric tonne of oil equivalent (MTOE) per year and above
6.	Aluminium	7,500 metric tonne of oil equivalent (MTOE) per year and above
7.	Railways	Electric traction Sub-Section (TSS), diesel loco shed, Production units and Workshops of Indian Railways having total annual energy consumption of 30,000 MTOE or more under Ministry of Railways
8.	Textile	3,000 metric tonne of oil equivalent (MTOE) per year and above
9.	Pulp & Paper	30,000 metric tonne of oil equivalent (MTOE) per year and above

Energy Conversion values used for working out annual energy consumption in terms of metric tonne of oil equivalent

For the purpose of this table

i) 1 kg of Oil Equivalent: 10000 kcal

ii) I Metric Tonne of Oil Equivalent (MTOE): 1 x 10^7 kcal

iii) In case of coal, petroleum products and other fuels in absence of supplier certificate. GCV of the above fuel (fuel sample) will be considered as per the test Certificate from a NABL Accredited Lab or State Government Laboratory or Government recognized Laboratory

As per the Act, Designated consumers have to fulfill the following criteria:

- Designated consumers have to appoint Energy managers with prescribed qualifications.
- The designated consumer has to get an energy audit conducted by an accredited energy auditor. Designated consumers would comply with prescribed norms and standards of energy consumption for the industrial sectors.
- Designated Consumers are required to adhere to energy efficient consumption norms stipulated.
- Designated Consumers are required to submit the status of energy consumption information every financial year as prescribed.

Perform, Achieve and Trade (PAT) Scheme is a market based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded. The genesis of the PAT mechanism flows out of the provision of the Energy Conservation Act, 2001 (amended in 2010).

The key goal of PAT scheme is to mandate specific energy efficiency improvements for the most energy intensive industries. Sector wise breakup of 478 Designated Consumers, which have

been notified under the Energy Conservation Act, 2001, and covered under PAT Scheme, is as given below:

Sector	Minimum annual energy consumption for the DC (tons of oil equivalent)	No. of DCs
Aluminium	7500	10
Cement	30000	85
Chlor-Alkali	12000	22
Fertilizer	30000	29
Iron and Steel	30000	67
Pulp and Paper	30000	31
Textile	3000	90
Thermal Power Plant	30000	144
Total		**478**

The scheme builds on the large variation in energy intensities of different units in almost every sector. The scheme envisages improvements in the energy intensity of each unit covered by it. The energy intensity reduction target mandated for each unit is dependent on its operating efficiency: the specific energy consumption reduction target is less for those who are more efficient, and is higher for the less-efficient units.

Further, the scheme incentivizes units to exceed their specified SEC improvement targets. To facilitate this, the scheme provides the option for industries who achieve superior savings to receive energy savings certificates for this excess savings, and to trade the additional certified energy savings certificates with other designated consumers(energy intensive industries notified as Designated Consumers under the Energy Conservation Act and included under PAT Scheme) who can utilize these certificates to comply with their specific energy consumption reduction targets. Energy Savings Certificates (ESCerts) so issued will be tradable at Power Exchanges. The scheme also allows units which gain ESCerts to bank them for the next cycle of PAT, following the cycle in which they have been issued. The number of ESCerts which would be issued would depend on the quantum of energy saved over and above the target energy savings in the assessment year (for 1st Cycle of PAT, assessment year is 2014-15).

After completion of baseline audits, targets varying from unit to unit ranging from about 3 to 7% have been set and need to be accomplished by 2014-15 and after which new cycle with new targets will be proposed. Failing to achieve the specific energy consumption targets in the time frame would attract penalty for the non-compliance under Section 26 (1A) of the Energy Conservation Act, 2001 (amended in 2010). For ensuring the compliance with the set targets, system of verification and check-verification will be carried out by empanelment criteria of accredited energy auditors.

Empanelment Criteria of Accredited Energy Auditor's Firm for Verification and Check-Verification under PAT Scheme

Accredited Energy Auditor can apply for Empanelment of Accredited Energy Auditor Firm for Verification and Check Verification under PAT Scheme and meet the following criteria for Firm empanelment:

(a) as at least one Accredited Energy Auditor whose name is included in the list of the Accredited Energy Auditors maintained by the Bureau under regulation 7 of the Bureau of Energy Efficiency (Qualifications for Accredited Energy Auditors and Maintenance of their List) Regulations, 2010;

(b) has at least three energy auditors (for definition of "energy auditor" refer Clause (c) of sub-regulation (1) of regulation 2 of the Bureau of Energy Efficiency (Qualifications for Accredited Energy Auditors and Maintenance of their List) Regulations, 2010;

(c) has adequate expertise of field studies including observations, probing skills, collection and generation of data, depth of technical knowledge and analytical abilities for undertaking verification and check-verification;

(d) has a minimum turnover of ten lakhs rupees per annum in at least one of the previous three years or in case of a newly formed organisation, a net worth of ten lakhs rupees

(In case an Accredited Energy Auditor is not the owner of a Firm, but works in a Firm and wish to get empanel the Firm, he/she may submit an authority letter from the authorized official of the Firm, in original, that the said Firm allow the Accredited Energy Auditor to apply for empanelment of the Firm with BEE for Verification and Check Verification under PAT Scheme and will abide by the mandatory provisions as listed in the notification)

2.3.7. Certification of Energy Managers and Auditors:

A cadre of professionally qualified energy managers and auditors with expertise in policy analysis, project management, financing and implementation of energy efficiency projects would be developed through Certification and Accreditation programme. BEE has been designing training modules, and regularly conducting a National level examination for certification of energy managers and energy auditors.

Qualification for Accredited Energy Auditors and Maintenance of their list, Regulations, 2009

An Energy auditor shall be qualified to become an accredited energy auditor if he / she-

(a) is a certified energy manager and has passed the examination in "Energy Performance for Equipment and Utility Systems" conducted by Bureau

(b) has an experience of five years in energy audit out of which atleast three years shall be in any of energy intensive industries

(c) has been granted a certificate of accreditation by the Bureau of Energy Efficiency.

Accreditation Advisory Committee constituted by BEE for the purpose of grant of certificate of accreditation shall assess the energy audit experience and competence of energy auditor who has applied for certification of accreditation on the basis of an oral interview.

2.4 Electricity Act, 2003

The government has enacted Electricity Act, 2003 which seeks to transform and develop the electricity sector by distancing Government from the task of regulation.

Before enactment of this act, electricity supply in India was governed by Indian Electricity Act, 1910, the Electricity (Supply) Act, 1948 and the Electricity Regulatory Commissions Act, 1998. There was a need to consolidate the provisions of above act and consequently, Electricity Act was introduced in 2003.

The objectives of the Act are

- To consolidate the laws relating to generation, transmission, distribution, trading and use of electricity
- To take measures suitable for development of electricity industry
- To promote competition
- To protect interest of consumers and supply of electricity to all areas,
- To ensure transparent policies regarding subsidies
- To promote efficient and environmentally benign policies
- To constitute Central Electricity Authority (CEA), Regulatory Commissions

Main features of Electricity Act 2003

- Generation free from licensing
- Captive generation free from control
- Re-structuring of State Electricity Boards
- Mandatory establishment of Regulatory Commissions
- Open access in transmission
- Open access in distribution to be allowed by State Regulators in phased manner
- Recognition of electricity trading as a distinct activity
- Stringent provisions for violation of grid discipline and theft of power
- Supply of electricity to all areas and specific provisions for supply in rural areas
- Rationalization of electricity tariff

Role of Government

Central Government will prepare National Electricity Policy and Tariff Policy, focus on rural areas permitting stand alone systems and non-conventional energy in consultation with States, bulk purchase

of power and distribution through Panchayats, Cooperative Societies, non-Government organisations, franchisees etc. The constitution of State Regulatory commission is a mandatory requirement. If subsidy is provided by Central /State Government, provision has to be created in the budget.

Rural Electrification

Goal of Government is to extend supply of electricity to all villages/hamlets. No licence is required for generation and distribution in rural area.

Generation

Generation is freed from licensing. Captive Generation is free from controls. Open access is allowed to Captive generating plants subject to availability of transmission facility. However, clearance of CEA for hydro projects is required due to concern of dam safety and inter-State issues. Generation from Non-Conventional Sources / Co-generation will be promoted. Minimum percentage of purchase of power from renewable energy sources may be prescribed by Regulatory Commissions.

Transmission

Transmission Utility at the Central as well as State level, to be a Government company with responsibility for planned and coordinated development of transmission network.

However, load despatch would be under control of Government as it is critical for grid stability and neutrality. Open access to the transmission lines would be provided to distribution licensees, generating companies. This would promote competitions and lead to gradual cost reduction. Private licensees would be allowed in transmission.

Distribution

Distribution would be licensed. Distribution licensees would be free to undertake generation and generating companies would be allowed to take up distribution businesses. Open access in distribution would be introduced in phases. Retail tariff would be determined by Regulatory commission. Metering of all electricity supplied would be made mandatory. Private licensees would be allowed in distribution.

Renewable energy

A significant regulatory impact on renewable energy was made by the Electricity Act, 2003, which provides for the determination of quotas or Renewable Purchase Obligation (RPO) by the State Electricity Regulatory Commissions (SERC). Internationally, this is commonly referred to as the Renewable Portfolio Standard (RPS). The RPS is a policy instrument that ensures that a minimum amount of renewable energy is included in the portfolio of resources.

The policy obligates each retail seller of electricity to include in its resource portfolio a certain proportion of power from renewable energy resources, such as wind, solar, small hydro and various forms of biomass energy. The retailer can satisfy this obligation by both owning a renewable energy facility and producing own power or purchasing power from someone's facility.

Consumer

- Consumer to be given connection within stipulated time.
- Penalty in case of failure to give connection
- Ombudsman scheme for consumers grievance redressal
- Regulatory commission to specify Electricity supply code to be followed by licensees
- Appellate Tribunal to hear appeals from consumer against the decision of the State and Central Regulatory commissions
- Licensees are required to meet standards of performance specified by Regulatory Commission. Failure to meet standards makes them liable to pay compensation to affected person within ninety days.

Trading / Market Development

Trading is being permitted with licensing under the safeguard of the Regulatory Commissions. Regulatory Commissions also have authority to fix ceilings on trading margins, if necessary to avoid artificial price fluctuations.

Role of Central Electricity Authority (CEA)

- to continue as the main technical Advisor of the Govt. of India/ State Government with the responsibility of overall planning.
- to specify the technical standards for electrical plants and electrical lines
- to be technical adviser to CERC as well as SERCs
- to specify the safety standards

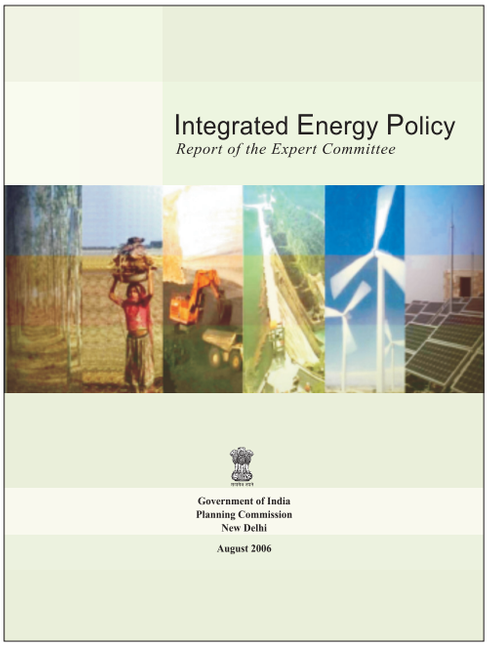
Tariff Principles

- Regulatory Commission is responsible to determine tariff for supply of electricity by generating company on long/medium term contracts.
- No tariff fixation by regulatory commission if tariff is determined through competitive bidding or where consumers, on being allowed open access, enter into agreement with generators/traders.
- Consumer tariff should progressively reduce cross subsidies and move towards actual cost of supply.

- State Government may provide subsidy in advance through the budget for specified target groups if it requires the tariff to be lower than that determined by the Regulatory Commission.
- Regulatory Commissions may undertake regulation including determination of multi-year tariff principles, which rewards efficiency and is based on commercial principles.
- Regulatory Commission will look at the costs of generation, transmission and distribution separately.

2.5 Integrated Energy Policy

Overview



The power supply position prevailing in the country is characterized by persistent power shortages, unreliability and also high prices for industrial consumer. India depends on imported oil to extent of over 70% and this raises energy security concerns. Also consistency in policies governing each sector and consistency in pricing of different types of energy is lacking. There is a need to establish clarity in the direction which we must follow in aspects like energy security, addressing environmental concerns, energy conservation and Research and Development. To achieve these objectives, Expert Committee has made a comprehensive review to make recommendations for integrated energy policy.

India needs to sustain 8% to 10% economic growth rate, over the next 25 years, if it is to eradicate poverty and meet its human development goals. To deliver a sustained growth rate of 8% through 2031-32 and to meet the lifeline energy needs of all citizens, India needs to increase its primary energy supply by 3 to 4 times and, its electricity generation capacity/supply by 6 to 7 times of their 2003-04 levels.

By 2031-32, power generation capacity must increase to nearly 8,00,000 MW from the current capacity of around 1,60,000 MW. Similarly requirement of coal will need to increase to over 2 billion tonnes/ annum based on domestic quality of coal.

This demand must be met through safe, clean and convenient forms of energy at the least cost in a technically efficient, economically viable and environmentally sustainable manner. Considering unpredictable nature of energy supply and disruptions, assured supply of energy is essential to providing energy security.

Coal will remain India's most important energy source till 2031-32 and beyond. Thus, India must seek clean coal combustion technologies and, given the growing demand for coal, also pursue new coal

extraction technologies such as in-situ gasification to tap its vast coal reserves that are difficult to extract economically using conventional technologies.

Need for Integrated Energy Policy

- Policies affecting energy are determined by different Ministries: Petroleum & Natural Gas, Coal, Power, Water Resources, Atomic Energy, New and Renewable Energy and Finance Ministry for tax purposes
- Policies in each sector have evolved independently across sectors and they do not take into account responses arising from climate change.
- Globally energy prices are rising and domestic energy prices have to reflect these changes to encourage energy efficiency, and to encourage domestic investment in expanding energy supply.

The main features of the Policy can be summed up as follows:

Reducing Energy Requirements through Energy Efficiency and Conservation

The focus is on lowering the energy intensity of GDP growth through higher energy efficiency for meeting India's energy challenge and ensuring its energy security.

Currently, India consumes 0.16 kg of oil equivalent (kgoe) per dollar of GDP. India's energy intensity is lower than the 0.23 kgoe of China, 0.22 kgoe of the US and a World average of 0.21 kgoe. India's energy intensity is even marginally lower than that of Germany and OECD at 0.17 kgoe. However, Denmark at 0.13 kgoe, UK at 0.14 kgoe and Brazil and Japan at 0.15 kgoe are ahead of India.

Many sectoral studies confirm that there is scope to improve and energy intensity can be brought down significantly in India with current commercially available technologies. Lowering energy intensity through higher efficiency is equivalent to creating a source of untapped domestic energy.

By implementing energy efficiency and conservation, it is possible to reduce energy intensity by up to 25% from current levels. Efficiency can be increased in energy extraction, conversion, transportation, as well as in consumption. Further, the same level of output or service can be obtained by alternate means requiring less energy. The major areas where efficiency in energy use can make a substantial impact are mining, electricity generation, electricity transmission, electricity distribution, water pumping, industrial production processes, haulage, mass transport, building design.

Other policy measures include,

- Establishing benchmarks of energy consumption for all energy intensive sectors.
- Increasing the gross efficiency in power generation from the current average of 30.5% to 34%. All new plants should adopt technologies that improve their gross efficiency from the prevailing 36% to at least 38-40%.

- Promoting minimum life cycle cost purchase instead of minimum initial cost procurement by the government and the public sector.
- Promoting urban mass transport, energy efficient vehicles and freight movement by railways through scheduled freight trains with guaranteed, safe and timely deliveries.
- Enforcing minimum fuel efficiency standards for all vehicles.
- Instituting specializations in energy efficiency/conservation in technical colleges and commence certification of such experts.

Ensuring Adequate Supply of Coal with Consistent Quality

The dominance of coal in India's energy mix will continue till 2031-32. Since decontrolling of price, the coal sector has become profitable as a result of price increases and increasing share of open cast production. India would need to augment domestic production and encourage thermal coal imports to meet its energy needs.

Along the coastal belts (especially western and southern coasts), cost of imported coal is cheaper than domestic coal. Necessary infrastructure must be created to handle thermal coal imports. This will facilitate coastal power generation capacity based on imported thermal coal. Imports of thermal coal will also put competitive pressure on the domestic coal industry to be more efficient.

For increasing domestic coal production, the plan seeks to release coal blocks held by Coal India Limited (CIL) that cannot be brought into production by 2016-17 to other eligible candidates (i.e. central and state public sector units) for bringing into production by 2011-12.

The Coal Mines (Nationalization) Act, 1973, to be amended to facilitate: (a) private participation in coal mining for purposes other than those specified in the Act and (b) offering of future coal blocks to potential entrepreneurs.

Other measures proposed are:

- To introduce a system of pricing coal based on its gross calorific value.
- To follow international practice of washing coal before use.
- To replace the current system of coal linkages by long-term coal supply agreements with strict penalties for not meeting contracted supplies, quality and off takes commitments.
- To bring coal under independent regulation to improve exploitation and allocation of available resources; to regulate e-auctions and coal prices; and to enable competitive market (proposed to sell 20% of domestic production to be sold through e-auction)

Ensuring Availability of Gas for Power Generation

There is a total generation capacity of over 12000 MW based on gas and liquid fuels, mostly under combined cycle operation. However, gas supplies have been restricted and the overall utilisation is low. Any new gas based power plant would be allowed to be built only with firm and bankable gas

supply agreements. Domestic gas would be allocated to fertilizer, petrochemicals, transport and power sector at prices that yield fair return to suppliers.

Other proposed measures include:

- Private investment will be sought in all energy sectors.
- Explore possibility of acquiring energy assets abroad
- Clarity and stability in policy to attract investment

Rationalization of Fuel Prices for Efficient Fuel Choice and Substitution

- Tax Policy should be uniform across sectors with specific differences for externality
- Regulation of coal prices to be replaced with market driven price.
- Coal price to be fully variable based on Gross Calorific value and other quality parameters
- Rational State and Central taxes on commercial energy supplies
- Environmental taxes and subsidies to affect choices of fuel

Accelerating Power Sector Reforms

Power Sector Reforms: The reforms focus on controlling the aggregate technical and commercial (AT&C) losses of the state transmission and distribution utilities. This is needed to create a financially sound power sector in each state. Only financially healthy state power distribution utilities can sustain the growing generation and transmission of Central Power Sector.

Accelerated Power Development and Reform Programme (APDRP) has to be restructured to ensure energy flow auditing at the distribution transformer level through automated meter reading, a Geographical Information System (GIS) mapping of the network and consumers and the separation of feeders for agricultural pumps.

Investment in developing a Management Information System (MIS) that can support a full energy audit for each distribution transformer is essential for reduction in AT&C losses. This will also fix accountability and provide a baseline which is an essential prerequisite to management reform and/or privatization.

It is proposed to rehabilitate thermal stations to raise capacity as a least cost short-term measure. Similarly, rehabilitation of hydro stations would be taken to yield peak power at lowest costs.

Rehabilitation of existing thermal stations to raise capacity at least cost as a short-term measure. Similarly, rehabilitations of hydro stations would yield peak power at lowest costs.

Reduction in Cost of Power

In terms of purchasing power parity, the power tariffs in India for industry, commerce and large households are among the highest in the world. It is important to reduce the cost of power to increase both the competitiveness of the Indian economy and also to increase consumer welfare.

The following measures are suggested:

- All generation and transmission projects should be competitively built on the basis of tariff-based bidding.
- Where tariff continues to be determined on the basis of costs and norms, regulators may either adopt a return on equity approach or return on capital approach, whichever is considered better in the interest of consumers.
- Unit sizes should be standardized and global tenders invited for a number of units to get substantial bulk discount.

Role for Renewable Energy

Renewable energy will play a key part in developing energy security. Even if renewable energy contribution is small, distributed nature of renewable energy provides various benefits such as environmental friendly nature of technology, less time for setting up the project. The main focus will be on solar power to attain energy independence in the future. For promoting renewable energy, incentives / capital subsidy would be linked to actual energy generated and not on capacity installed.

Several initiatives are proposed to boost renewable energy:

- Grid connected renewable to improve quality of supply and provide system benefits by generating energy at the ends of the grid where supply would have been poor.
- Other forms of renewable energy to be promoted include fuel wood plantations, bio-gas plants, wood gasifier based power plants, solar thermal, solar water heaters, solar photovoltaics, bio-diesel and ethanol.
- Incentives should be linked to energy generated and not on capacity installed. Subsidy in the form of Tradable Tax Rebate Certificate (TTRC) proposed based on actual energy generated. The rebate claim would become payable depending upon the amount of electricity / energy certified as having been actually supplied.
- Mandatory feed-in-laws or differential tariffs to encourage utilities to integrate wind, small hydro, cogeneration into their systems.
- Feed in tariff or RPS (Renewable Portfolio Standard) for efficiency proposed.

Ensuring Energy Security

India's energy security is primarily about ensuring the continuous availability of commercial energy at competitive prices to support its economic growth and meet the energy needs of its households with safe, clean and convenient forms of energy even if that requires directed subsidies.

India's growing dependence on energy imports exposes its energy needs to external price shocks and hence, domestic energy resources must be expanded. All available domestic energy resources have to be exploited to the maximum as long as they are competitive.

Reducing energy requirements and increasing efficiency are the two very important measures to increase energy security.

Energy security risks can be reduced by lowering the requirement of energy by increasing the efficiency in production and use; by substituting imported fuels with domestic fuels; by diversifying fuel choices (gas, ethanol, tar sands etc.) and supply sources; and by expanding the domestic energy resource base. Risks can also be reduced by increasing the ability to withstand supply shocks through creation of strategic reserves, the ability to import energy and face market risk by building hard currency reserves and by providing redundancy to address technical risks (generator failure, transmission line trips, oil pipe line leaks etc.).

Recommendations include,

- Increasing exploration to find more coal, oil and gas
- Maintaining a reserve, equivalent to 90 days of oil imports for buffer stock purposes and/or buy options for emergency supplies from neighbouring large storages such as those available in Singapore.
- Addressing short-term price volatility through creation of buffer stocks. Operating the strategic/ buffer reserves in cooperation with other countries who maintain such reserves could also increase their effectiveness.
- In-situ coal gasification
- Extracting coal bed methane from coal mines
- Adopting enhanced oil recovery technologies
- Extracting isolated deposits of all hydro carbons including coal through private sector
- Developing the thorium cycle for nuclear power
- Exploiting non-conventional energy, especially solar power

In addition, India can access cheap natural gas overseas under long-term agreements (i.e. 20-30 years) and it can consider setting up captive fertilizer and / or gas liquefaction facilities in such countries.

Role of Nuclear and Hydro Power

The developments of hydropower, especially storage schemes, are critical for India as our per capita water storage is the lowest among other comparable countries. Reducing such storages is critical to India's water security, flood control and drought control. However, the environmental concerns and the problem of resettlement and rehabilitation must be suitably addressed.

India is poorly endowed with Uranium. Available Uranium can meet needs of only upto 10000 MW of nuclear power. Uranium ore is of low grade containing only upto 0.1% Uranium compared with 12-14% Uranium in resources abroad. Hence, our nuclear power is 2-3 times costlier than international supplies.

Three stage strategy of development of nuclear power from pressurized heavy water reactor to fast breed reactor and finally to Thorium based reactors is being planned.

Promoting and focusing energy related R&D

National Energy Fund is being planned to finance energy R&D on a competitive basis as it is felt that energy related R&D is not being allocated the resources that it needs. Such R&D would help in raising energy security and delivering energy independence over long-term. It is also proposed to develop number of research institutions as centres of excellence in energy research.

A number of technology missions should be mounted for developing near commercial technologies and rolling out new technologies in a time bound manner. These include coal technologies for efficiency improvement; in-situ gasification, IGCC and carbon sequestration, solar technologies covering solar thermal and photovoltaic, bio-fuels such as bio-diesel and ethanol, bio-mass plantation and wood gasification, and community based bio-gas plants.

Climate Change Concerns

Concern and the threat of climate change has been an important issue in formulating the energy policy. Initiatives suggested to reduce the green house gas intensity of the economy by as much as one third are:

- Energy efficiency in all sectors
- Emphasis on mass transport
- Active policy on renewable energy including bio-fuels and fuel plantations
- Accelerated development of nuclear and hydro-electricity
- Technology Missions for clean coal technologies
- Focused R&D on many climate friendly technologies

2.6 National Action Plan on Climate Change (NAPCC)

India is faced with the challenge of sustaining its rapid economic growth while dealing with the global threat of climate change. This threat comes from accumulated anthropogenic greenhouse gas emission in the atmosphere generated through long term, energy intensive industrial growth and high consumption lifestyle. India is very vulnerable to climate: floods, droughts, vector borne disease, cyclones, ocean storm surges, etc. and at the same time the country does neither have the sufficient infrastructure nor the resources to face its impacts.

Climate change may drastically alter the distribution and quality of India's natural resources and harm the livelihood of its people. With an economy closely linked to its natural resources base and climate sensitive sector such as agriculture, water & forestry, India may face a major threat because of climatic change.

India needs a national strategy to firstly, adapt to climate change and secondly to improve the ecological sustainability while pursuing India's development path. Recognizing the urgency to chart an action plan to address the consequences of climate change, NAPCC document was released in 2008 and it identifies measures to advance India's development without affecting climate change related adaptation and mitigation.

Guiding Principles of NAPCC

- Protecting the poor and vulnerable sections of the society through sustainable development strategy sensitive to climate change.
- Achieving national growth objectives, while enhancing ecological sustainability leading to mitigation of greenhouse gas emissions.
- Devising efficient and cost-effective strategies for Demand Side Management.
- Deploying appropriate technologies for both adaptation and mitigation of greenhouse gases emissions extensively as well as rapidly.
- Engineering new and innovative forms of market, regulatory and voluntary mechanisms to promote sustainable development.
- Effecting implementation of programmes and projects through local government institutions and public private partnership.

NAPCC outlines a number of steps to simultaneously advance India's development and climate change-related objectives of adaptation and mitigation.

Eight National Missions

There are eight National Missions which form the core of the National Action Plan are:

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for Green India
- National Mission for Sustainable Agriculture
- National Mission for Strategic Knowledge on Climatic Change

National Solar Missions : India is a tropical country, where sunshine hours are long and with high intensity. Solar Energy, therefore, has great potential as a future energy source. At present efficiency levels, 1% of land area is sufficient to meet electricity needs of India till 2031. It also has the advantage of permitting a decentralized distribution of energy, thereby empowering people at the grassroots level. There is need to create affordable and more convenient solar power systems and enable storage of solar power for sustained long term use.

A National Solar Mission is being launched to significantly increase the share of solar energy in the total energy mix as well to increase the use of other renewable and non-fossil fuel options such as nuclear energy, wind energy and biomass.

National Mission for Enhanced Energy Efficiency: The Energy Conservation Act of 2001 provides a legal mandate for the implementation of the energy efficiency measures through the institutional mechanism of Bureau of Energy Efficiency (BEE) in the Central Government and designated agencies in each state. A number of schemes and programmes have been initiated under the Act and implemented by BEE has resulted in avoided capacity addition of 10836 MW the XI Plan.

The National Mission for Enhanced Energy Efficiency (NMEEE) aims to strengthen the market for energy efficiency by creating conducive regulatory and policy regime and has envisaged fostering innovative and sustainable business models to the energy efficiency sector.

The mission was approved for two years of the 11th Plan period (2010 -11 and 2011-12) with an outlay of Rs.235.50 crore and continuation of the mission for XII Plan was approved with an outlay of Rs. 775 crores.

The NMEEE spelt out four initiatives to enhance energy efficiency in energy intensive industries which are as follows:

1. **Perform Achieve and Trade Scheme (PAT)**, a market based mechanism to enhance the cost effectiveness in improving the Energy Efficiency in Energy Intensive industries through certification of energy saving which can be traded.

2. **Market Transformation for Energy Efficiency (MTEE)**, for accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable.

3. **Energy Efficiency Financing Platform (EEFP)**, for creation of mechanisms that would help finance demand side management programmes in all sectors by capturing future energy savings.

4. **Framework for Energy Efficient Economic Development (FEEED)**, for development of fiscal instruments to promote energy efficiency.

The Mission seeks to upscale the efforts to unlock the market for energy efficiency which is estimated to be around Rs. 74,000 crore and help achieve total avoided capacity addition of 19,598 MW, fuel savings of around 23 million tonnes per year and green house gas emissions reductions of 98.55 million tonnes per year at its full implementation stage.

PAT is currently under implementation and nearing completion of its first cycle of three years that started in 2012-13 after the notification of mandated specific energy consumption reduction targets for 478 Designated Consumers from 8 energy intensive sectors that include Aluminum, Cement, Chlor- Alkali, Fertilizer, Iron & Steel, Paper & Pulp, Thermal Power, Textile. The SEC reduction targets aim to secure an energy saving of 6.686 million tonne of oil equivalent. PAT is a multicycle

scheme and in the subsequent cycles more units within the existing sectors and more sectors will be included to bring the energy efficiency of the economy to a higher level.

Under MTEE, two programmes have been developed i.e. Bachat Lamp Yojana (BLY) and Super Efficient Equipment Programme (SEEP) to bring market transformation for highly efficient appliances/ equipment. The Bachat Lamp Yojana (BLY) that was instrumental in the market transformation of CFLs, its institutional structure is envisaged to be used for promotion of LEDs. The other component under MTEE is a new programme called SEEP which is designed to bring accelerated market transformation for super efficient appliances by providing financial stimulus innovatively at critical point/s of intervention. Under this program, ceiling fan has been identifies as the first appliance to adopted. The goal is to support the introduction and deployment of super efficient 35W ceiling fans, as against the current average ceiling fan sold in Indian market with about 70W rating by providing incentives to fan manufacturers.

EEFP provides platform where financial institutions, ESCOs and government work together for the development of energy efficiency market and for the identification of issues related to this market development. MOUs are signed with financial institutions to promote financing for energy efficiency projects. Further, capacity building exercises such as development of training modules, and training for financial institutions on energy efficiency project financing.

Two funds have been created viz. Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE) and Venture Capital Fund for Energy Efficiency (VCFEE) under FEEED to provide partial coverage of risk involved in extending loans for energy efficiency projects provide guarantee and to provide equity capital for energy efficiency projects respectively.

National Mission on Sustainable Habitat : A National Mission on Sustainable Habitat is planned to make habitat sustainable through improvements in energy efficiency of buildings, management of solid waste and shift to public transport. The mission will promote energy efficiency as an integral component of urban planning and urban renewal through three initiatives.

The Energy Conservation building code, which addresses the design of new and large commercial building to optimize their energy demand, will be extended in its application and incentives provided for retooling existing building stock.

Recycling of material and Urban Waste Management will be a major component of ecologically sustainable economic development. India already has a significantly higher rate of recycling of waste compared to developed countries. A special area of focus will be the development of technology for producing power from waste. The national Mission will include a major R&D programme, focusing on bio chemical conversion, wastewater use, and sewage utilization and recycling options wherever possible.

Better urban planning and modal shift to public transport. Making long-term transport plans will facilitate the growth of medium and small cities in ways that ensure efficient and convenient public transport.

National Water Mission: National Water Mission focuses on ensuring integrated water resource management to conserve water, minimize wastages and ensuring equitable distribution across and within States.

Under provisions of National Water Policy, the following goals are set:

- Enhancing water use efficiency by 20%
- Recycling of waste water to meet large part of water needs of urban areas
- Adoption of new and appropriate technologies such as low temperature desalination for coastal cities
- Basin level management strategies such as rain water harvesting etc.
- Improving efficiency of existing irrigation systems, recharging of underground water sources, and adoption of large scale irrigation programmes.

National Mission for Sustaining the Himalayan Ecosystem: This mission focuses on sustaining and safeguarding the Himalayan glacier and mountain ecosystem. The extent to which Himalayan glacier is receding and problems to be addressed will be studied. Observation and monitoring network will be set up to assess fresh water resources and health of ecosystem. Community based management of Himalayan ecosystems will be promoted with incentives to community organizations and panchayats for protection and enhancement of forest lands.

National Mission for a Green India: Green India initiative will focus on enhancement of ecosystem services including carbon sinks. Green India campaign is already being launched for afforestation of 6 million hectares. The Mission aims to increase land area under forest and tree cover from the current level of 23% to 33%.

National Mission for Sustainable Agriculture: The Mission aims to make Indian agriculture more resilient to climate change. It would identify and develop new varieties of crops and especially thermal resistant crops and alternative cropping patterns, capable of withstanding extremes of weather, long dry spells, flooding, and variable moisture availability.

Agriculture will need to be progressively adapted to projected climate change and the agricultural research systems must be oriented to monitor and evaluate climate change and recommend changes in agricultural practices accordingly.

This will be supported by the convergence and integration of traditional knowledge and practice systems, information technology, geospatial technologies and biotechnology. New credit and insurance mechanisms will be devised to facilitate adoption of desired practices.

Focus would also be on improving productivity of rainfed agriculture.

National Mission on Strategic Knowledge for Climate Change: Mission would identify challenges and responses to climatic change through enlisting global community in research, technology development and collaboration. It will ensure funding of high quality and focused research into various aspects of climate change.

The Mission will also have on its research agenda, socio-economic impacts of climate change including impact on health, demography, migration patterns and livelihoods of coastal communities. It would also support the establishment of dedicated climate change related academic units in Universities and other academic and scientific research institutions in the country which would be networked.

A Climate Science Research Fund would be created under the Mission to support research. Private sector initiatives for development of innovative technologies for adaptation and mitigation would be encouraged through venture capital funds. Research would be undertaken through identified centres to support policy and implementation. The Mission will also focus on dissemination of new knowledge based on research findings.

List of Acts, Rules & Regulations relevant to Energy Managers and Energy Auditors

No	Title
1.	THE ENERGY CONSERVATION ACT, 2001 [Act 52 of 2001, dt. 29-9-2001] [As amended by Act No. 28 of 2010, dt. 4-8-2010]
2.	THE ENERGY CONSERVATION (THE FORM AND MANNER FOR SUBMISSION OF REPORT ON THE STATUS OF ENERGY CONSUMPTION BY THE DESIGNATED CONSUMERS) RULES, 2007 [GSR 174(E), dt. 2-3-2007]
3.	THE ENERGY CONSERVATION (FORM AND MANNER AND TIME FOR FURNISHING INFORMATION WITH REGARD TO ENERGY CONSUMED AND ACTION TAKEN ON RECOMMENDATIONS OF ACCREDITED ENERGY AUDITOR) RULES, 2008 [GSR 486(E), dt. 26-6-2008]
4.	THE ENERGY CONSERVATION (INSPECTION) RULES, 2010 [GSR 645(E), dt. 27-7-2010, w.e.f. 30-7-2010]
5.	THE BUREAU OF ENERGY EFFICIENCY (QUALIFICATIONS FOR ACCREDITED ENERGY AUDITORS AND MAINTENANCE OF THEIR LIST) REGULATIONS, 2010 [Notification No. 02/11(7)/09-BEE, dt. 31.3.2010]
6.	THE BUREAU OF ENERGY EFFICIENCY (CERTIFICATION PROCEDURES FOR ENERGY MANAGERS) REGULATIONS, 2010 [Notification No. 2/11(2)/07-BEE, dt. 15-10-2010]
7.	THE BUREAU OF ENERGY EFFICIENCY (MANNER AND INTERVALS OF TIME FOR CONDUCT OF ENERGY AUDIT) REGULATIONS, 2010 [Noti. No. 02/11(6)/05-BEE, dt. 28-4-2010]
8.	ENERGY CONSUMPTION NORMS AND STANDARDS FOR DESIGNATED CONSUMERS, GSR 269 (E) dt 30th March, 2012
9.	ENERGY CONSERVATION (MINIMUM QUALIFICATION FOR ENERGY MANAGERS) RULES, 2006. G.S.R. 309 dt. 8th December, 2006

10.	ENERGY CONSERVATION (FORM AND MANNER AND TIME FOR FURNISHING INFORMATION WITH REGARD TO ENERGY CONSUMED AND ACTION TAKEN ON RECOMMENDATIONS OF ACCREDITED ENERGY AUDITOR) RULES, 2008. G.S.R. 486 (E) dt 26th June, 2008
11.	(ALTERED) LIST OF ENERGY INTENSIVE INDUSTRIES AND OTHER ESTABLISHMENTS SPECIFIED IN THE SCHEDULE TO THE SAID (EC) ACT S.O. 394 (E) dt 12th March, 2007
12.	APPELLATE TRIBUNAL FOR ENERGY CONSERVATION (PROCEDURE, FORM, FEE AND RECORD OF PROCEEDINGS) RULES, 2012 GS.R. 510(E) dt 28th June, 2012

The full references of these are available in the BEE website.

Solved Example:

In a textile plant the average monthly energy consumption is 7,00,000 kWh of purchased electricity from grid, 40 kL of furnace oil (specific gravity =0.92) for thermic fluid heater, 60 tonne of coal for steam boiler, and 10 kL of HSD (sp.gravity = 0.885) for material handling equipment.

Given data:

(1 kWh = 860 kcal, GCV of coal= 3450 kcal/kg, GCV of furnace oil= 10,000 kcal/kg, GCV of HSD= 10,500 kcal/kg, 1kg oil equivalent = 10,000 kcal)

a) Calculate the energy consumption in terms of Metric Tonne of Oil Equivalent (MTOE) for the plant.
b) Calculate the percentage share of energy sources used based on consumption in MTOE basis.
c) Comment whether this textile plant qualifies as a notified designated consumer under the Energy Conservation Act?

Ans:

a) (40000 x0.92x 10000) + (60000 x 3450) + (7,00,000 x 860) + (10,000x 0.885 x 10,500)

$$\text{MTOE} = \frac{(36.8 \times 10^7) + (20.7 \times 10^7) + (60.2 \times 10^7) + (9.2925 \times 10^7)}{10^7}$$

= 127 Metric Tonnes of Oil Equivalent per month

b) Electricity % = 47.4, Furnace oil% =29.0, Coal % =16.3, HSD% =7.3

c) Annual energy consumption of the textile plant = 127 x 12 = 1524 MTOE which is less than 3000 MTOE cut off limit as notified under the EC act. Therefore this textile plant is not a designated consumer for the present energy consumption levels.

QUESTIONS	
Objective Type Question	
1	The legal framework for energy efficiency in India is given by a) Electricity Act 2003 b) Energy Conservation Act 2001 c) Electricity (supply) Act 1958 d) Indian Electricity Act 1910
2	The first amendment to the Energy Conservation Act was made in a) 1948 b) 2003 c) 2007 d)2010
3	The nodal agency at the centre for implementing the EC act is a) CEA b) SDA c) BEE d) Ministry of Power
4	The minimum connected load for a building as defined in the amended EC act is a) 100 kW b) 100 kVA c) 500 kW d) 500 kVA
5	As per EC act, the definition of energy audit does not consider a) monitoring b) verification c) analysis d) duration of audit
6	Star rating is a part of _____ programme of BEE a) DSM b) BLY c) S&L d) none of the above
7	For the purpose calculating MTOE for a designated consumer the calorific value of oil is taken as a) 10,500 kcal/kg b) 10,000 kcal/kg c) 10,400 kcal/kg d) 9,800 kcal/kg
8	The norms for energy consumption in ECBC is defined as energy consumption per_____ a) day b) hour c) square foot d) square meter
9	DSM is of benefit to a) Government b) DISCOM c) user d) all of the above
10	The major portion of subsidy under BLY is met be revenues from a) electricity boards b) CDM c) DISCOMS d) central budget
Short Type Questions	
S-1	Explain what is meant by Renewable Purchase Obligation (RPO)
S-2	Explain the reforms in the distribution brought about by Electricity Act 2003
S-3	Explain the difference between Standards and Labelling?
S-4	List at least five national missions under the National Action Plan for Climatic Change
S-5	Distinguish between designated agency and designated consumer
Long Type Questions	
L-1	Explain the 'Bachat Lamp Yojana' scheme
L-2	Explain five important features of the energy conservation act, 2001?

REFERENCES

1. *National Action Plan on Climate Change* prepared by Prime minister's Council on Climate Change

2. Integrated Energy Policy *Report of the Expert Committee* (August 2006*)* prepared by Planning Commission New Delhi

http://www.bee-india.nic.in/

http://www.energymanagertraining.com

Chapter 3

Basics of Energy and its Various Forms

Learning Objectives

In this chapter you will learn about

- Energy types & forms
- Stages in energy conversion
- Terms and definitions used in electrical energy
- Terms and definitions used in thermal energy
- Energy- units and conversion
- MTOE conversions

3. BASICS OF ENERGY AND ITS VARIOUS FORMS

Electricity basics - DC & AC currents, Electricity tariff, Thermal basics - Fuels, Thermal energy contents of fuel, Temperature & pressure, Heat capacity, Sensible and latent heat, Evaporation, Condensation, Steam, Moist air and humidity, Heat transfer, Units and conversion, MTOE conversions

3.1 Introduction

Energy is described as the ability to do work or as the ability to carry a heat transfer. Energy is required for doing work or involving in a heat transfer. A body is said to possess energy when it has the capacity to do work or the capacity to carry a heat transfer with another body. Work and heat transfer are the transfer of energy from one body to another-so they are called transitory energy. In practical terms energy is what we use to manipulate the world around us, whether by exciting our muscles, by using electricity or by using mechanical devices such as automobiles.

Broadly, energy can be classified as potential (stored) energy and kinetic (working) energy.

Potential Energy

Potential energy is the energy a body possesses because of its position or configuration. For example, driving head of a pile driver has potential energy of position when raised above. On release, driving head comes down to do the piling work. Stretched rubber band or compressed steel spring possesses potential energy of configuration. Both have ability to do work because of their tendency to return to their normal position. Potential energy exists in various forms: chemical energy, nuclear energy, stored mechanical energy, gravitational energy etc.

Potential energy stored in a body due to its height above a datum level is expressed by:

Potential energy (E_p) = mass x gravitational acceleration x height= m g h.

Chemical Energy

Chemical energy is the energy stored in the bonds of atoms and molecules and released as heat in a chemical reaction. This is specific to each reaction and is usually given as energy unit mass (e.g. kJ/kg) or number of molecules (e.g. kJ/mol). Biomass, petroleum, natural gas, propane and coal are examples of stored chemical energy.

Nuclear Energy

Nuclear energy is the energy stored in the nucleus of an atom - the energy that holds the nucleus together. The nucleus of an Uranium atom releases nuclear energy when its' fission (split in two parts) results in a loss of mass and the corresponding loss of mass(m) is converted to nuclear energy by following famous equation of Einstein:

Nuclear energy (E_n) = mass x speed of light squared = m c^2 (where c = 3 x 10^8 m/s)

Stored Mechanical Energy

Stored mechanical energy is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy.

Gravitational Energy

Gravitational energy is the energy of place or position. Water in a reservoir behind a hydropower dam is an example of gravitational energy. When the water is released to spin the turbines, it becomes motion energy **in the form of mechanical power-which drives the Generators/Alternators to produce electrical energy.**

Kinetic Energy

It is the energy a body possesses by virtue of motion or velocity. For example, a moving vehicle, a flowing fluid and moving parts of machinery all have kinetic energy because of their motion. It exists in various forms: radiant energy, thermal energy, electrical energy, motion energy, sound energy, electrical energy etc.

Kinetic energy (E_k) = ½ mv^2 = half x mass x velocity squared = 1/2 x m x v^2

Radiant Energy

Radiant energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Solar energy is an example of radiant energy.

Thermal Energy

Thermal energy is the internal energy in substances - the vibration and movement of atoms and molecules within substances. Geothermal energy is an example of thermal energy.

Motion energy

The movement of objects or substances from one place to another is motion. Wind and hydropower are **manifestations of motion energy.**

Sound energy

Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves.

Electrical Energy

Electrical energy is the movement of electrons. Lightning and electricity are examples of electrical energy.

3.2 Work, Energy and Power

Work

The *unit of work* or energy is the joule (J) where one joule is one Newton meter. The joule is defined as the work done or energy transferred when a force of one Newton is exerted through a distance of one meter in the direction of the force. Energy is the capacity for doing work.

Thus, Work done on a body, in Joules $W = Fs$

Where, F is the force in Newtons and s is the distance in meters moved by the body in the direction of the force.

In case of rotating body work done is expressed in Joules as: $W = T*(\theta/2\pi)$

Where T is the Torque in Newton-Meter and θ is the angle in radian the body rotated.

Kilojoule (1 kJ = 1000J) is more common among engineers. Even kilojoule is too small a unit when considering national or global amounts of energy. In such cases Megajoule (10^6J), Gigajoule (10^9J), terrajoule (10^{12}J) and petajoule (10^{15}J) are used.

Energy and Power

Energy represents potential to do work. To actually do the work, one has to use energy of one form at a given rate and convert to another form. Power is defined as the rate of doing work or rate at which energy is used and converted.

The *unit of power* is Watt (W), where one Watt is one Joule per second.

Thus, power in Watts, $P = W/t$

Where, W is the work done or energy transferred in Joules and t is the time in seconds.

Thus, energy, in joules, $W = Pt$

1 kWh = 3600KJ =3.6MJ

In case of rotating body, power in Watts, $P=T*w= (2\pi*T*N)/60,$

Where T is the Torque applied in Newton-Meter, w is angular velocity in radian/sec. and N is the revolution per minute(RPM).

Example 3.1

A portable machine requires a force of 200 N to move it. How much work is done if the machine is moved 20 m and what average power is utilized if the movement takes 25 s?

Solution

Work done = force x distance

= 200 N x 20 m

= 4000 Nm or 4 kJ

Power = Work done / time taken = 4000 J /25 s = 160 J/s =160 W

3.3 Electricity Basics

Direct Current (DC)

A current which is a non-varying, unidirectional current, e.g. current produced by batteries.

Alternating Current

A current which reverses in regularly recurring intervals of time and which has alternate positive and negative values occurring specified number of times., e.g. current from utilities. In 50 Cycle (Hertz) AC, current reverses direction 100 times per second i.e. two times in one cycle.

Amps or Ampere (A)

Current is the rate of flow of charge. Ampere is the basic unit of electric current.

Voltage or Volts (V)

It is a measure of electric potential or electromotive force. A potential of one Volt (V) appears across a resistance of one Ohm when a current of one Ampere flows through the resistance. In case of Alternating Current (AC) –the Voltage or Current value normally mentioned is Root Mean Squared (RMS) value so that we can use the same formula for calculating power just like a Direct Current (DC) application.

Resistance and Conductance

The *unit of electric resistance* is the *ohm* (Ω) where one ohm is one volt per ampere. It is defined as the resistance between two points in a conductor when a constant electric potential of one volt applied at the two points produces a current flow of one ampere in the conductor. Thus, resistance, in ohms

$$R = Volts / Amp = V/I$$

where V is the potential difference across the two points in volts and I is the current flowing between the two points in amperes.

The reciprocal of resistance is called *conductance* and is measured in siemens (S). Thus, conductance, in mho or Siemens $G = 1/R$, where R is the resistance in ohms.

Frequency (Hertz)

The supply frequency is the number of cycles at which alternating current changes. The unit of frequency is cycles / second or Hz. In India-the normal supply frequency by utilities is at 50 Hz.

Electrical Energy

When a direct current (DC) of *I* amperes is flowing in an electric circuit and the voltage across the circuit is V volts, then,

$$\textbf{\textit{Power, in Watts } } P = VI$$

$$\textbf{\textit{Electrical energy = Power x time}}$$

$$= V \times I \times t \text{ Joules}$$

The same formulae can be used in AC applications as well (since voltage and current are normally expressed in RMS values for AC applications)

Although the unit of energy is the Joule, when dealing with large amounts of energy, the unit used is the *kilowatt hour* (kWh) where

1 kWh = 1000 Watt hour

= 1000 x 3600 Watt seconds or Joules

= 3,600,000 J

Example 3.2

An electric heater consumes 1.8 MJ when connected to a 250 V supply for 30 minutes. Find the power rating of the heater and the current taken from the supply?

Solution

Energy = power x time,

Power = Energy / time

= 1.8×10^6 J / 30 x 60s

= 1000 J/s = 1000 W

i.e., Power rating of heater = 1 kW

Power $P = VI$ thus, $I = P/V = 1000/250 = 4$ A

Hence, the current taken from the supply is 4 A.

Example 3.3

A 100 W electric light bulb is connected to a 250 V supply. Determine (a) the current flowing in the bulb, and (b) the resistance of the bulb

Solution

Power P = V x I from which, current I = P/V

(a) Current, I = 100/250 =0.4 A

(b) Resistance, R = V/I =250/0.4 = 625 Ω

Example 3.4

An electric kettle has a resistance of 30 Ω . What current will flow when it is connected to a 240 V supply? Find also the power rating of the kettle.

Solution

Current, I = V/R = 240/30 = 8 A

Power, P = VI = 240 x 8 = 1920 W

= 1.92 kW

= Power rating of kettle

Example 3.5

A 100 W electric light bulb is connected to a 250 V supply. Determine (a) the current flowing in the bulb, and (b) the resistance of the bulb

Solution

Power P = V x I from which, current I = P/V

(a) Current, I = 100/250 = 0.4 A

(b) Resistance, R = V/I = 250/0.4 = 625 W

Example 3.6

An electric heater of 230 V, 5 kW rating is used for hot water generation in an industry. Find electricity consumption per hour (a) at the rated voltage (b) at 200 V.

Solution

(a) Electricity consumption (kWh) at rated voltage = 5 kW x 1 hour = 5 kWh.

(b) Electricity consumption at 200 V (kWh) = $(200 / 230)^2$x 5 kW x 1 hour = 3.78 kWh.

Power Factor

The total power requirement is comprised of two components, as illustrated in the power triangle, Figure 4-1. This diagram shows the resistive portion or kilowatt (kW), 90° out of phase with the reactive portion, kilovolt ampere reactive (kvar). The reactive current is necessary to build up the flux for the magnetic field of inductive devices, but otherwise it is non-usable. The resistive portion is also known as the active power which is directly converted to useful work. The hypotenuse of the power triangle is referred to as the kilovolt ampere or apparent power (kVA). The angle between kW and kVa is the power factor angle.

kW $= kVA \cos \theta$

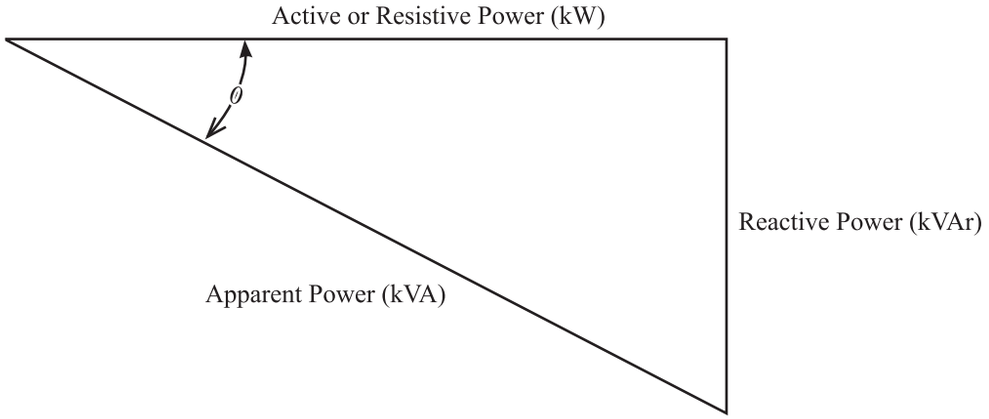
$kVA = kW / \cos \theta$

$kVAR = kVA \sin \theta$

$PF = \cos \theta$

PF is referred to as the power factor.

Only power portions in same phase with each other can be combined. For example: resistive portions of one load can be added to resistive portions of another. The same will hold for reactive loads also.



Relationships between Power, Voltage, and Current

For a balanced three-phase load,

$$Power, Watts = \sqrt{3}\, V_L \, x \, I_L \, Cos\theta$$

For a balanced single-phase load,

$$Power, Watts = V_L \, x \, I_L \, Cos\theta$$

Where,

V_L = Line Voltage

I_L = Line current.

Which applications use single-phase power in an industry?

Single-phase power is mostly used for lighting, fractional HP motors and electric heater applications.

Example 3.7

A 400 Watt mercury vapor lamp was switched on for 10 hours per day. The supply volt is 230 V. Find the energy consumption per day? (Volt = 230 V, Current = 2 amps, PF = 0.8)

Solution

Electricity consumption (kWh) = V x I x Cos Φ x No of Hours

= 0.230 x 2 x 0.8 x 10 = 3.7 kWh or Units

Motor Loads

Each electrical load in a system has an inherent power factor. Motor loads are usually specified by horsepower ratings. These may be converted to kVA, by use of Equation

$$kVA = (HP \times 0.746)/(\eta \times PF)$$

Where,

η = Motor efficiency

P.F. = Motor power factor

HP = Motor horsepower (i.e. Rated Output power).

Most motor manufacturers can supply information on motor efficiencies and power factors. Smaller motors running partly loaded are the least efficient and have the lowest power factor.

Example 3.8

A 3-phase AC induction motor (20 kW capacity) is used for pumping operation. Electrical parameters such as current, volt and power factor were measured with power analyzer. Find the energy consumption of motor in one hour? (Volts. = 440 V, current = 25 amps and PF = 0.90).

Solution

Measured Energy consumption = $\sqrt{3}$ x 0.440 x 25 x 0.90 **x 1** = 17.15 kWh

Motor loading calculation

The name plate details of motor, KW or HP indicates the output of the motor at full load The other parameters such as volt, amps , PF are the input condition of motor at full load.

Example 3.9

A 3-phase 10 kW motor has the name plate details as 415 V, 18.2 amps and 0.9 PF. Actual input measurement shows 415 V, 12 A and 0.7 PF which was measured with power analyzer during motor running. Find out the motor loading and actual input power of the motor.

Solution

Rated output at full load = 10 KW

Rated input at full load = 1.732x0.415x18.2x0.9 = 11.8 kW

The rated efficiency of motor = 10/11.8 = 85%

Measured (Actual) input power = 1.732x 0.415 x 12x 0.7 = 6.0 kW

$$\textbf{Motor loading (\%)} = \frac{\text{Measured kW}}{\text{Rated Input kW}} = \frac{6.0}{11.8} \times 100 = 51.2\ \%$$

3.4 Thermal Energy Basics

Temperature

Temperature is a physical property that quantitatively expresses the common notions of hot and cold. Objects of low temperature are cold, while various degrees of higher temperatures are referred to as warm or hot.

Temperature is measured with thermometers, which may be calibrated to a variety of temperature scales. Much of the world uses the Celsius scale for most temperature measurements. In Fahrenheit scale (British system), the freezing point of water is 32°F and the boiling point of water is 212°F at atmospheric pressure.

The Kelvin scale is the temperature standard for scientific or engineering purposes. It has the same incremental scaling(1°) as the Celsius scale, but fixes its origin, or null point, at absolute zero (0K = −273.15°C)

Conversion of the degree Celsius into Fahrenheit = (degrees C x 1.8) + 32

Conversion of the Fahrenheit into degree Celsius = (degrees F - 32) / 1.8

Degrees Celsius (C) to degrees Kelvin (K) = (C) + 273 = (K)

Pressure

It is the force per unit area applied to outside of a body.

$$\mathbf{P = F/A = ma/A = mg/A\ (when\ g=a)}$$

Where,

P is the pressure in N/m^2 or Pascals
F is the force in Newtons (N)
a is the acceleration in m/s^2
g is the acceleration due to gravity in m/s^2

Absolute pressure

The **absolute pressure (*ps*)** is total or true pressure. It is measured relative to the *absolute zero pressure* **-** the pressure that would occur at absolute vacuum. All calculation involving the gas laws requires pressure to be in absolute units and temperature in Kelvin.

Gauge Pressure

Gauge pressure (*pg*) is the pressure indicated by a gauge. All gauges are calibrated to read zero at atmospheric pressure. Gauges indicated the pressure difference between a system and the surrounding atmosphere. The **gauge pressure** can be expressed as

$$pg = ps - pa$$

Where,

pg = gauge pressure
ps = system pressure (absolute)
pa = atmospheric pressure

Atmospheric Pressure

Atmospheric pressure (*pa)* is pressure in the surrounding air at the surface of the earth. The atmospheric pressure varies with temperature and altitude above sea level.

Standard Atmospheric Pressure

Standard Atmospheric Pressure (*atm*) is used as a reference for gas densities and volumes. The Standard Atmospheric Pressure is defined at sea-level at *273°K (0°C)* and is ***1.01325 bar*** or *101325 Pascal (absolute)*. The temperature of *293°K (20°C) is* also used.

1 atm = 1.01325 bar = 101.3 kPa= 760 mmHg =10.33 meter H_2O = 1013 mbar = 1.0332 kg_f/cm^2

Heat

Heat is transferred from one body to another body at a lower temperature by virtue of temperature difference i.e. Heat is energy in transition or transitory energy.

The quantity of heat depends on the quantity and type of substance involved.

Calorie is the unit for measuring the quantity of heat. It is the quantity of heat, which can raise the temperature of 1 g of water by 1°C.

Calorie is too small a unit for many purposes. Therefore, a bigger unit Kilocalorie (1 Kilocalorie = 1000 calories) is used to measure heat. 1 kilocalorie can raise the temperature of 1000g (i.e. 1kg) of water by 1°C.

However, nowadays generally Joule as the unit of heat energy is used. It is the internationally accepted unit. Its relationship with calorie is as follows:

1 Calorie = 4.187 J
≈ 4.2 J

Specific Heat

If the same amount of heat energy is supplied to equal quantities of water and milk, their temperature goes up by different amounts. This is due to different specific heats of different substances. Specific heat is defined as the quantity of heat required to raise the temperature of 1kg of a substance through 1°C or 1 K. Specific heat is expressed in terms of kcal/kg°C or J/kg K. Specific heat varies with temperature. In case of gases-there are an infinite number of processes in which heat may be added to raise gas temperature by a fixed amount and hence a gas could have an infinite numbers of specific heat capacities. However-only two specific heats are defined for gases i.e. specific heat at constant pressure, c_p and specific heat at constant volume ,c_v. For solids and liquids, however, the specific heat does not depend on the process.

The specific heat of water is very high as compared to other common substances; it takes a lot of heat to raise the temperature of water. Also, when water is cooled, it gives out a large quantity of heat. The specific heats of common substances are given in Table 3.1.

Table 3.1 Specific Heat of Some Common Substances

Substance	Specific heat (J/kg°C)
Lead	130
Mercury	140
Copper	390
Aluminium	910
Water	4200
Alcohol	2400
Iron	470

Sensible Heat

The amount of heat which when added to any substance causes a change in temperature. The changes in temperature that do not alter the moisture content of air. It is expressed in calories or Joules.

Sensible heat = mass x specific heat x change in temperature

$$Q = m\, C_p\, \Delta T$$

Phase Change

The change of state from the solid state to a liquid state is called fusion. The fixed temperature at which a solid changes into a liquid is called its melting point.

The change of a state from a liquid state to a gaseous is called vaporization. The fixed temperature at which a liquid changes into a vapour is called its boiling point. The change of a state from gaseous state to a liquid state is called condensation.

Latent heat

It is the change in heat content of a substance, when its physical state is changed without a change in temperature.

Latent heat of fusion

The latent heat of fusion of a substance is the quantity of heat required to convert 1 kg solid into liquid state without change of temperature. It is represented by the symbol h_{if}. Its unit is Joule per kilogram (J/Kg) Thus, Q_L (ice) = 335 KJ/kg. The change in phase occurs in either direction at the fusion temperature i.e. liquid to solid and solid to liquid. The temperature and quantity of heat to bring about the change will be the same in either case and can be determined from the following equation:

$$\boldsymbol{Q_L = m \; x \; h_{if}}$$

Where Q_L = The quantity of latent heat in kilojoules

m = The mass in kg

h_{if} = The latent heat of fusion in kJ/kg

Example 3.10

If the latent heat of fusion of water is 335 kJ/kg, determine the quantity of latent heat given up by 10 kg of water at 0°C when it freezes into ice at 0°C.

Q_L = 10 kg x 335 kJ/kg = 3350 kJ

Example 3.11

If 20 kJ of heat is supplied to 25 kg of ice at 0°C, how many kilograms of ice will be melted into water?

$m = Q_L/h_{if}$ = *20 kJ/335 kJ/kg = 0.06 kg*

Latent Heat of Vaporization

The quantity of heat that a 1 kg mass of liquid will absorb in going from the liquid phase to the vapour phase, or give up in going from the vapour phase to the liquid phase, without change in temperature, is called latent heat of vaporization.

It is also denoted by the symbol Q_L and its unit is J/kg. The latent heat of vaporization of water is 2257 KJ/kg. When 1 kg of water at 100°C vaporizes to form steam at 100°C, it absorbs 2257 kcal/kg (540 kcal/kg) of heat.

$$Q_L = m \; x \; h_{fg}$$

Where,

Q_L = The quantity of latent heat in kilojoules
m = The mass in kg
h_{fg} = The latent heat of vaporization in kJ/kg

Condensation

Condensation is the change by which any substance is converted from a gaseous state to liquid state without change in temperature. When 1 kg of steam at 100 condenses to form water at 100°C, it gives out 2260 kJ of heat.

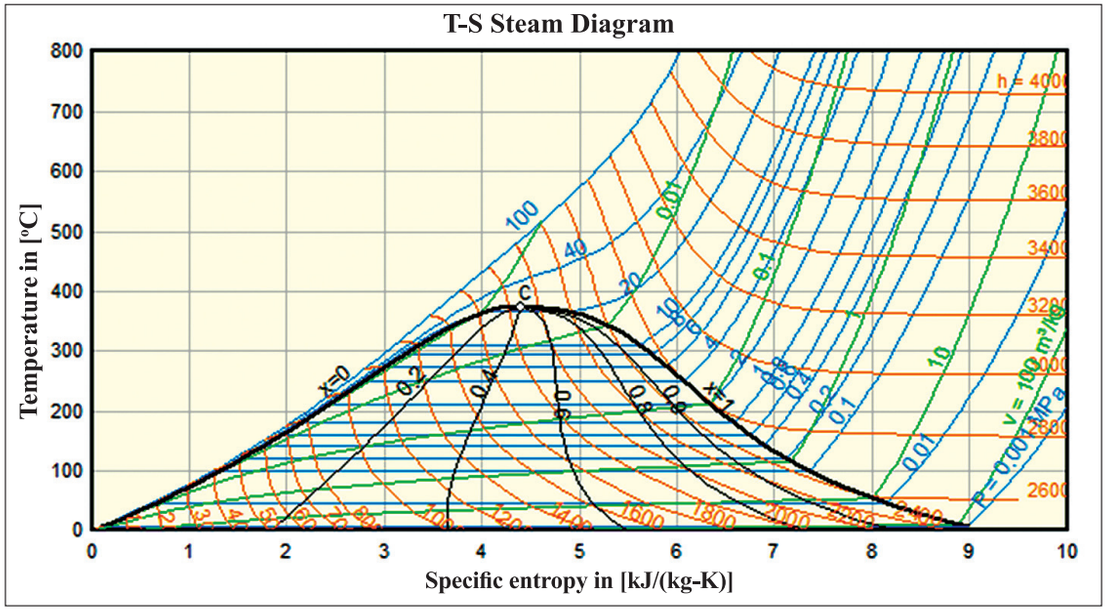
Example 3.12

Determine the quantity of heat required to vaporize 2 m^3 of water at 100°C if the latent heat of vaporization of water at that temperature is 2257 kJ/kg

Q_L = 2000 kg x 2257 kJ/kg = 4514000 kJ

Super Heat

Super heating is the heating of vapour, particularly saturated steam to a temperature much higher than the boiling point (also called saturation temperature) at the existing pressure. This is done in power plants to improve efficiency and to avoid condensation in the turbine. Here it is noteworthy to mention that higher the pressure of water-higher the saturation temperature at corresponding pressure. This property of water can be depicted by the following Temperature- entropy(T-S) diagram:



Entropy in horizontal axis is commonly understood as a measure of disorder of a substance.

The area under the dome is the binary phase i.e. water and steam mixture. The blue lines are constant pressure line and these lines under the dome represent the latent heat region (i.e. constant temperature and pressure heating resulting into phase change from water to steam).

X=dryness factor of steam=in 1 kg of water-steam mixture, x kg is mass of steam and (1-x) kg is mass of water.

Thus the zone in right side of X=1.0 line represents the superheated region of steam**.**

Humidity

Moisture contained in air is expressed as Humidity. Saturated air holds all the moisture it can at that temperature and pressure.

The unit for humidity is kg of moisture / kg of dry air.

Dew Point

It is the temperature at which water vapor in the air becomes saturated with moisture and the moisture starts to condense into water droplets. It is equal to the saturation temperature at the partial pressure of the water vapour in the mixture.

Specific Humidity or Humidity Ratio

It is the mass (kg) of the water vapor in each kg of dry air (kg/kg).

Relative Humidity (RH)

It is the ratio of mass of water vapour actually held by the air in a given volume to that which air could hold at the same temperature if the air were saturated. It is expressed as a percentage. Warmer air will hold more water vapour and saturated air cannot hold any more water vapour.

Relative humidity affects comfort conditions. An air sample that is at 50% RH is holding half the moisture it is capable of holding at the same temperature (at dew point or saturated).

Dry bulb and Wet bulb Temperatures

Dry bulb measures sensible heat content in air-vapour mixtures. Dry bulb temperature is not influenced by RH. It is the temperature recorded by the thermometer with a dry bulb.

Wet bulb thermometer has wick saturated with distilled water enveloping the bulb of the thermometer. The evaporation of water lowers temperature, taking the latent heat from the water-soaked wick-thus decreasing the temperature recorded. Wet bulb temperature takes into account RH.

If relative humidity is 100%, dew point, wet bulb and dry bulb temperatures are all the same.

Enthalpy of air

It is the measure of total heat content of air and water vapor mixture measured from pre-determined base point. It is expressed as kcal/kg or Joules/kg. Enthalpy of air stream can be determined by measuring dry and wet bulb temperature and referring the psychometric chart.

Fuel Density

Density is the ratio of the mass of the fuel to the volume of the fuel at a stated temperature. Density is expressed in kg/m^3.

Specific gravity of fuel

The specific gravity of fuel is the ratio of density of fuel to that of water. The specific gravity of water is defined as 1. As it is a ratio there are no units. Higher the specific gravity, higher will be the heating values. Specific gravity has no dimensions.

Viscosity

The viscosity of a fluid is a measure of its internal resistance to flow. All liquid fuels decrease in viscosity with increasing temperature.

Viscosity is measured in Stokes / Centistokes. Sometimes viscosity is quoted in Engler, Saybolt or Redwood.

Energy Content in Fuel

Energy content **(Calorific Value)** in an organic matter can be measured by burning it and measuring the heat released. This is done by placing a sample of known mass in a bomb calorimeter, a device that is completely sealed and insulated to prevent heat loss. A thermometer is placed inside (but it can be read from the outside) and the increase in temperature after the sample is burnt completely is measured. From this data, energy content in the organic matter can be found out.

The heating value of fuel is the measure of the heat released during the complete combustion of unit weight of fuel. It is expressed as Gross Calorific Value (GCV) or Net Calorific Value (NCV). The difference between GCV and NCV is the heat of vaporization of the moisture and atomic hydrogen (conversion to water vapour) in the fuel. Typical GCV and NCV for heavy fuel oil are 44100 J/kg (10,500 kcal/kg) and 41160 J/kg (9,800 kcal/kg).

Heat transfer

Heat will always be transferred from hot to cold independent of the mode. The energy transferred is measured in Joules. The rate of energy transfer, more commonly called heat transfer, is measured in Watts (J/s)

Heat is transferred by three primary modes:

- Conduction (Energy transfer in a solid)
- Convection (Energy transfer in a fluid)
- Radiation (doesn't need a material to travel through)

Conduction is the primary mode of heat transfer through solid. Conduction occurs by two mechanisms

- ✓ Molecular Motion. Molecules of higher energy (motion) impart that energy to adjacent molecules of lesser energy.
- ✓ Migration of free electrons. This is primarily associated with pure metals

Convection occurs when a fluid exchanges energy with an adjacent solid. The fluid motion adjacent to the solid surface assists in the transfer of energy

There are two types of convection heat transfer:

- ✓ Forced convection - Fluid motion is induced by an external source such as a fan or pump
- ✓ Natural convection - Heating a fluid results in natural convection heating. Air will circulate due to natural convective heating. The temperature gradient in the fluid creates variations in density within the fluid. The colder fluid (heavier) will sink, and the hotter fluid (lighter) will rise.

Radiation mode heat transfer requires no medium for the transport of heat. Energy can be radiated from a body over a wide range of wavelengths. Thermal radiation is only a small portion of the electromagnetic spectrum shown and it encompasses infrared light to ultraviolet light. Radiant energy that strikes a surface can be reflected, absorbed and transmitted.

Steam Properties

Evaporation

When a liquid evaporates it goes through a process where

- ✓ The liquid heats up to the evaporation temperature
- ✓ The liquid evaporate at the evaporation temperature by changing state from fluid to gas
- ✓ The vapor heats above the evaporation temperature - superheating

The heat transferred to a substance when temperature changes is often referred to as sensible heat. The heat required for changing state as evaporation is referred to as latent heat of evaporation.

The most common vapor is evaporated water - steam.

Enthalpy of steam

Enthalpy of a system is defined as the mass of the system - m - multiplied by the specific enthalpy - h - of the system and can be expressed as:

$$H = m\ h$$

Where,

H = enthalpy (kJ)
m = mass (kg)
h = specific enthalpy (kJ/kg)

Specific Enthalpy

Specific enthalpy is a property of the fluid and can be expressed as:

$$h = u + p\ v$$

Where,

u = internal energy (kJ/kg)
p = absolute pressure (N/m^2)
v = specific volume (m^3/kg)

Part of the water vapor - steam - properties can be expressed in a table as:

p (bar)	***t_s (^oC)***	***v_f (m^3/kg)***	***v_g (m^3/kg)***	***u_f (kJ/kg)***	***u_g (kJ/kg)***	***h_f (kJ/kg)***	***h_g (kJ/kg)***	***s_f (kJ/kg.K)***	***s_g (kJ/kg.K)***
0.006112	0.01	0.0010002	206.1	0	2,375	0.0006	2,501	0	9.155
0,010	7.0	0.0010001	129.2	29	2,385	29	2,514	0.106	8.974
1.01325	100.0	0.001044	1.673	419	2,507	419	2,676	1.307	7.355
220	373.7	0.00269	0.00368	1,949	2,097	2,008	2,178	4.289	4.552
221.2	374.15	0.00317	0.00317	2,014	2,014	2,084	2,084	4.430	4.430

- *s* is the steam entropy
- suffix - *f* - referrer to saturated liquid
- suffix - *g* - referrer to saturated vapor – steam
- *p (bar) in terms of absolute pressure i.e pg +pa*

Specific Enthalpy of Saturated Water

Specific enthalpy of saturated water - h_f - can be obtained from tables as above. The value depends on the pressure.

For saturated water at standard atmosphere -the specific enthalpy - h_f - is *419 kJ/kg*. At standard atmosphere - *1 bar (14.7 psi)* - water starts boiling at *100 °C (212 °F).*

The specific enthalpy of water (in SI units) can be calculated from:

$$h_f = c_w (t_f - t_0)$$

Where,

h_f = enthalpy of water (kJ/kg)
c_w = specific heat of water = 4.19 (kJ/kg.°C)
t_f = saturation temperature (°C)
t_0 = refer temperature = 0 (°C)

Specific Enthalpy of Saturated Steam

Specific enthalpy of saturated steam - h_g - can be obtained from tables as above. The value depends on the pressure.

For saturated steam at standard atmosphere - the specific enthalpy - h_g - is *2676 kJ/kg*.

The specific enthalpy of evaporation can be calculated from:

$$h_e = h_g - h_f$$

Where,

h_e = specific evaporation enthalpy (kJ/kg)

Specific evaporation enthalpy for water at standard atmosphere is:

h_e = *(2676 kJ/kg) - (419 kJ/kg)*

= *2257 (kJ/kg)*

Specific Enthalpy of Superheated Steam

The specific enthalpy of superheated steam can be calculated from:

$$h_s = h_g + c_{ps} (t_s - t_f)$$

Where,

h_s = Enthalpy of superheated steam (kJ/kg)

c_{ps} = Specific heat of steam at constant pressure = 1.860 (kJ/kg ^oC)

t_f = Saturation temperature (^oC)

t_s = Superheated steam temperature (^oC)

c = 1.860 (kJ/kg ^oC) at standard atmosphere. Note that c varies with temperature.

The laws of thermodynamics

Thermodynamics is the study of heat and work, and the conversion of energy from one form into another. There are actually three laws of thermodynamics, although the majority of thermodynamics is based on the first two laws.

The first law of thermodynamics

The first law of thermodynamics is also known as the *law of conservation of energy*. It states that the energy in a system can neither be created nor destroyed. Instead, energy is either converted from one form to another, or transferred from one system to another. The term 'system' can refer to anything from a simple object to a complex machine. If the first law is applied to a heat engine, such as a gas turbine, where heat energy is converted into mechanical energy, then it tells us that no matter what the various stages in the process, the total amount of energy in the system must always remain constant.

The second law of thermodynamics

While the first law of thermodynamics refers to the quantity of energy that is in a system, it says nothing about the direction in which it flows. It is the second law which deals with the natural direction of energy processes. For example, according to the second law of thermodynamics, heat will always flow only from a hot object to a colder object.

Another term arising from the second law of thermodynamics is the term 'entropy' which means disorder. Entropy can be used to quantify the amount of useful work that can be performed in a system. In simple terms, the more chaotic or disorderly a system, the more difficult it is to perform useful work.

It is the second law of thermodynamics that accounts for the fact that a heat engine can never be 100% efficient. Some of the heat energy from its fuel will be rejected to the surroundings, with the result that it will not be converted into mechanical energy.

The third law of thermodynamics

The third law of thermodynamics is concerned with absolute zero (i.e. -273 ^oC). It simply states that it is impossible to reduce the temperature of any system to absolute zero.

3.5 Energy Units and Conversions

SI system has 6 base units on which other units are derived. The base units are:

Base quantity	Name	Symbol
Length	meter	m
Time	Second	S
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of substance	Mole	Mol
Luminous intensity	Candela	cd

The examples of derived units from base units are:

Derived quantity	Name	Symbol
Area	Square meter	m^2
Volume	Cubic meter	m^3
Acceleration	Meter per second Squared	m/s^2
Mass density	Kilogram per cubic meter	kg/m^3
Specific volume	Cubic meter per kilogram	m^3/kg
Luminance	Candela per square meter	Cd/m^2

SI derived units are given special names and symbols for better understanding. Some derived SI units relevant to Energy Management & Audit are listed below:

Derived quantity	Name	Symbol	Expression in terms of other units	Expression in terms of base unit
Frequency	Hertz	Hz	-	s^{-1}
Force	Newton	N	-	$m \cdot kg \cdot s^{-2}$
Pressure	Pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
Energy, work, quantity of heat	Joule	J	N-m	$m^2 \cdot kg \cdot s^{-2}$
Power	Watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
Electric potential difference, electromotive force	Volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
Capacitance	Farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	Ohm		V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	Siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$

Celsius temperature	degree Celsius	°C	-	K
luminous flux	lumen	lm	cd·sr [(c)]	$m^2 \cdot m^{-2} \cdot cd = cd$
Illuminance	lux	lx	lm/m^2	$m^2 \cdot m^{-4} \cdot cd = m^{-2} \cdot cd$

Temperature Units

Conversion of the degree Celsius into Fahrenheit = degrees C x 1.8 + 32
Conversion of the Fahrenheit into degree Celsius = (degrees F - 32.) / 1.8

Degrees Celsius (C) to degrees Kelvin (K) = (C) + 273.15 = (K)

Pressure Units

1 atm	760 mm Hg	atmosphere (standard)
1 atm	101325 Pa	atmosphere (standard)
1 bar	100000 Pa	bar
1 cmHg (0 °C)	1333.22 Pa	centimetre of mercury (0 °C)
1cm H_2O	98.0638 Pa	centimeter of water (4 °C)
1 kgf/cm^2	98066,5 Pa	kilogram force per square centimetre
1 kgf/m^2	9,80665 Pa	kilogram force per square meter
1 kPa	1000 Pa	kilopascal
1 MPa	1000000 Pa	megapascal
1 mbar	100 Pa	millibar
1 N/m^2	1 Pa	pascal
1 lbf/ft^2	6894,76 Pa	pound force per square inch

Energy Units and Conversions

1 Joule	= 1 Watt/s
1 kW	= 1000 W
1 kWh	= 3.6 x 10^6 J = 3.6 million Joules
1 Mega-joule	= 278 Wh
1 Watt-hour (Wh)	= 3600 Joules
1 British thermal unit (BTU)	= 252 Cal
1 BTU	= 1055 J
1 Btu/h	= 0.293071 Wh
1 Kilocalorie/hour (kcal/h)	= 1163 Wh
1 HP	= 745.7 Watts

Energy Conversion values used for working out annual energy consumption in terms of metric tone of oil equivalent (as per Gazette of India Part II Sec 3 Sub-sec(ii) 19-03-2007)

- 1 kWh - 860 kilocalories (kcal)
- 1 kg. Coal/Coke - Gross Calorific Value as per supplier's (coal company's) latest certificate
- 1 kg. Charcoal - 6,900 kcal or as per supplier's latest certificate
- 1 kg. Furnace Oil/RFO/LSHS/NAPTHA - 10,050 kcal (density = 0.9337 kg/litre) or as per supplier's latest certificate
- 1 kg. HSD - 11,840 kcal (density = 0.8263 kg/litre) or as per supplier's latest certificate
- 1 kg. Petrol - 11,200 kcal (density = 0.7087 kg/litre) or as per supplier's latest certificate
- 1 kg. Kerosene - 11,110 kcal (density of SKO = 0.7782 kg/litre) or as per supplier's latest certificate.
- 1 kg. LPG - 12,500 kcal or as per supplier's latest certificate
- 1 m^3 Natural Gas - 8,000-10,500 kcal (Actual calorific value as per supplier's latest certificate may be considered. In case of non-issue of certificate by the supplier, average of the range 8000 -10,500 kcal/m^3 may be considered).

For the purpose of this table

- ✓ 1 kg of Oil Equivalent: 10,000 kcal
- ✓ 1 Metric Tonne of Oil Equivalent (MTOE) : 1 x 10^7 kcal
- ✓ In case of coal, petroleum products and other fuels in absence of supplier certificate, GCV of the above fuel (fuel sample) will be considered as per the test Certificate from a NABL Accredited Lab or State Government Lab or Gov. recognized Lab

For different type of fuel these following formulas can be used for MTOE conversion:

1. For solid fuel,
   (Quantity of solid fuel used in kg X GCV of fuel used in kcal/kg)/10^7
2. For Liquid fuel,
   (Quantity of liquid fuel used in kg or liters X GCV of fuel used in kcal/kg or liters)/10^7
3. For gaseous fuel,
   (Quantity of gaseous fuel used in kg or Nm^3 X GCV of fuel used in kcal/kg or Nm^3)/10^7

QUESTIONS	
Objective Type Questions	
1.	An example of stored mechanical energy is a) water in a reservoir b) an arrow in a stretched bow c) an air-borne aeroplane d) you on top of a mountain
2.	Mega Volt Ampere (MVA) in a three phase electrical circuit could be written as a) $\frac{\text{Voltage x Ampere}}{1000}$ b) $\frac{\text{Voltage x Ampere}}{1{,}000{,}000}$ c) Voltage x Ampere x1,000 d) none of the above
3.	When the current lags the voltage in an alternating current system, it is caused mainly due to a) resistive load b) capacitive load c) inductive load d) none of the above
4.	Which energy source is indirect in an overall energy balance in the generation of electricity by a photovoltaic cell? a) commercial energy b) wave energy c) sun lightd) none of the above
5.	The rate of energy transfer from a higher temperature to a lower temperature is measured in a) kcal b) Watt c) Watts per Second d) none of the above
6.	What is the "toe" of 125 Ton of coal which has GCV of 4000 kcal / kg a) 40 b) 50 c) 400 d) 500
7.	The quantity of heat required to raise the temperature of a substance by 1^{o} C is known as a) sensible heat b) specific heatc) heat capacity d) latent heat
8.	Active power in an alternating current (AC) circuit is given by a) kVA x power factor b) $(kVA^2 - kVAr^2)^{1/2}$ c) $[(kVA + kVAr) \times (kVA - kVAr)]^{1/2}$ d) all of the above
9.	Nameplate kW or HP rating of a motor indicates a) input kW to the motor b) output kW of the motor c) minimum input kW to the motor d) maximum input kW to the motor
10.	Among which of the following fuel is the difference between the GCV and NCV maximum? a) coal b) furnace oil c) natural gas d) rice husk
Short Type Questions	
S-1	List five forms of energy with examples.
S-2	A 10 kW rated motor has a full load efficiency of 85%. Actual input measurement at a particular loading shows 415 Volt, 10 Amps, and PF of 0.68. Find out the motor loading in percentage.

S-3	A 250 W sodium vapor lamp is installed on a street. The supply voltage for the streetlight is 230 V and it operates for around 12 hours in a day. Considering the current of 2 amps and power factor 0.85 calculate the energy consumption per day.
S-4	What is the load factor of a continuously operating facility that consumed 900,000 kWh of energy during a 30-day billing period and established a peak demand of 2000 kW?
S-5	A 400 Watt mercury vapor lamp was switched on for 10 hours per day. The supply volt is 230 V. Find the energy consumption per day? (Volt = 230 V, Current = 2 amps, PF = 0.8)
Long Type Questions	
L-1	Define the following: a) specific heat b) power factor
L-2	Define the following a) relative humidity b) wet bulb temperature c) dew point

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Chapter 4

Energy Management and Audit

Learning Objectives

In this chapter you will learn about

- Understanding energy management
- Building energy management function
- Skill-set for effective energy management
- How to conduct a preliminary energy audit?
- How to conduct a detailed energy audit?
- How to write an energy audit report?
- Importance of benchmarking
- Energy audit instruments

4. ENERGY MANAGEMENT AND AUDIT

Definition, Energy audit, Need, Types of energy audit. Energy management (audit) approach, Understanding energy costs, Benchmarking energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments and metering, Manner and intervals of EA regulation.

4.1 Definition and Objectives of Energy Management

The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect. The definition of energy management is:

"The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions" (or)

"The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems"

The objectives of Energy Management include,

- ✓ To achieve and maintain optimum energy procurement and utilisation, throughout the organization
- ✓ To minimise energy costs / waste without affecting production and quality
- ✓ To minimise environmental effects.

Successful energy management must combine an effective strategy with the right practical action. It begins with the key decision makers, and then involves every employee on a day-to-day basis. Many organisations would like to save energy, but to have the most impact and success, they need to give priority to energy management and make it an integral part of company management strategy.

4.2 Energy Audit Definition

Energy Audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial Energy Audit is fundamental to a comprehensive energy management programme and is defined in EC Act 2001 as follows:

"Energy Audit" means the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption.

4.3 Need for Energy Audit

In any industry, the three top operating costs are often found to be energy (both electrical and thermal), labour and materials. Among the three, energy has the highest potential for cost reduction. Energy audit will help to understand more about the ways energy is used in the industry, and help in identifying the areas where waste can occur and where scope for improvement exists. Such an audit programme will review variations in energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc. In general, energy audit is the translation of conservation ideas into realities, by evolving technically feasible solutions with economic and other organizational considerations within a specified time.

4.4 Types of Energy Audit and Approach

The type of energy audit to be performed depends on the type of industry, the depth to which final audit is needed, and the potential and magnitude of cost reduction desired. Thus energy audit can be classified into the following types: Preliminary Audit, Targeted Energy Audits and Detailed Audit.

Preliminary Energy Audit

Preliminary energy audit, which is also known as Walk-Through Audit and Diagnostic Audit, is a relatively quick exercise and uses existing, or easily obtained data. The scope of preliminary energy audit is to:

- Establish energy consumption in the organization (sources: energy bills and invoices)
- Obtain related data such as production for relating with energy consumption
- Estimate the scope for energy savings
- Identify the most likely and the easiest areas for attention (e.g. unnecessary lighting, higher temperature settings, leakage etc.)
- Identify immediate (especially no-/low-cost) improvements/ savings
- Set up a *baseline* or *reference point* for energy consumption
- Identify areas for more detailed study/measurement

Some example of no-cost energy management measures are:

- Arresting leaks (steam, compressed air)
- Controlling excess air by adjusting fan damper

Some examples of low-cost energy management measures are:

- Shutting equipment when not needed (e.g. idle running of motors)
- Replacement with appropriate lamps and luminaires

Areas for detailed study/measurement are:

- Converting from direct to indirect steam heated equipment and recovery of condensate
- Installing / upgrading insulation on equipment

- Modifying process to reduce steam demand
- Investigating scheduling of process operations to reduce peak steam or water demands
- Evaluating waste heat streams for potential waste heat recovery

Targeted Energy Audits

Targeted energy audits often results from preliminary audits. They provide data and detailed analysis on specified target projects. For example, an organization may target its lighting system or boiler system or steam system or compressed air system with a view of effecting energy savings. Targeted audits therefore involve detailed surveys of the target subjects and analysis of the energy flows and cost associated with the targets. Final outcome is the recommendations regarding actions to be taken.

Detailed Energy Audit

Detailed energy audit is a comprehensive audit and results in a detailed energy project implementation plan for a facility, since it accounts for the energy use of all major equipment. It considers the interactive effects of various projects and offers the most accurate estimate of energy savings and cost. It includes detailed energy cost saving calculations and project implementation costs.

One of the key elements in a detailed energy audit is the energy balance. This is based on an inventory of energy-using systems, assumptions of current operating conditions, measurements and calculations of energy use.

Detailed energy auditing is carried out in three phases: a) Pre Audit Phase b) Audit Phase and c) Post Audit Phase. A comprehensive ten-step methodology for conducting detailed energy audit is suggested as follows. However, methodology is flexible and can be adapted depending upon the industry concerned.

Ten Steps Methodology for Conducting Detailed Energy Audit

Step No	PLAN OF ACTION	PURPOSE / RESULTS
PHASE I –PRE AUDIT PHASE		
Step 1	• **Plan and Organise** • **Walk through Audit** • **Informal Interview** with Energy Manager, Production / Plant Manager	• Establish/organize a **Energy audit team** • Organize Instruments and time frame • Macro data collection (suitable to type of industry.) • Familiarization with process / plant activities • First hand observation and Assessment of current level of operation and practices
Step 2	• **Introductory Meeting** with all divisional heads and persons concerned with energy management (1-2 hrs.)	• To built up cooperation and rapport • Orientation, awareness creation • Issue questionnaire tailored for each department

PHASE II –AUDIT PHASE		
Step 3	• **Primary data gathering, Process Flow Diagram and Energy Utility Diagram**	• Historic data collection and analysis for setting up **Baseline energy consumption** • All service **utilities system diagram** (e.g. Single line power distribution diagram, water, and compressed air and steam distribution). • Prepare **process flow charts** • Design, operating data and schedule of operation • Annual Energy Bill and **energy consumption pattern** (Refer manual, logbook, name plate etc.)
Step 4	• **Conduct survey and monitoring**	• **Measurements** : Motor survey, Insulation, lighting survey etc. with portable instruments for operating data. Confirm and compare operating data with design data.
Step 5	• **Conduct of detailed trials** / tests for selected major energy equipment	• **Trials / Tests** - 24 hours power monitoring (MD, PF, kWH etc.). - Load variations trends in pumps, fan compressors etc. - Boiler Efficiency trials for (4-8 hours) - Furnace Efficiency trials - Equipments Performance tests etc
Step 6	• **Analysis of energy use**	• **Energy and Material balance** • **Energy loss/waste analysis**
Step 7	• **Identification and development of Energy Conservation (ENCON) opportunities**	• Conceive, develop and refine ideas • Review ideas suggested by unit personnel • Review ideas suggested in previous energy audit report if any • Use brainstorming and value analysis techniques • Contact vendors for new / efficient technology
Step 8	• **Cost benefit analysis**	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • Select the most promising projects • Prioritise by low, medium, long term measures
Step 9	• **Reporting and Presentation** to the Top Management	• Documentation, draft Report Presentation to the top Management. • Final report preparation on feedback from unit
PHASE II –POST AUDIT PHASE		
Step 10	• **Implementation and Follow-up**	**Implementation of ENCON recommendation measures** and Monitor the performance • Action plan, schedule for implementation • Monitoring and periodic review

Phase I – Pre Audit Phase

An initial study of the site should always be carried out as proper planning is a pre-requisite for an effective audit. An initial site visit should take only one day and gives the Energy Auditor an opportunity to meet the personnel concerned, to familiarize with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the Energy Auditor/Engineer should carry out the following actions:

- Discuss with the site's senior management about the aims of the energy audit.
- Explain the purpose of the audit and indicate the kind of information needed during the facility tour
- Discuss economic guidelines associated with the recommendations of the audit.
- Analyze the major energy consumption data with the relevant personnel.
- Obtain site drawings where available – plant / building layout, steam distribution, compressed air distribution, electricity distribution etc.
- Tour the site accompanied by site representative.

Typically, Energy Auditor should ask,

1. What function does this system serve?
2. How does this system serve its function?
3. What is the energy consumption of this system?
4. What are the indications that this system is probably working?
5. If this system is not working, how can it be restored to good working conditions?
6. How can the energy cost of this system be reduced?

The outcome of this visit should be:

- To finalise Energy Audit team
- To know the expectation of management from the audit
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify existing instrumentation and additional metering required prior to audit e.g. for measurement of electricity, steam, oil or gas consumptions
- To plan for audit with time frame
- To collect macro data on plant energy resources, major energy consuming equipments
- To build up awareness and support for detailed energy audit

Phase II – Detailed Energy Audit Phase

Depending on the nature and complexity of the site, a detailed audit can take from several weeks to several months to complete. Detailed studies would involve investigation and establishment of material and energy balances for specific plant departments or process equipment. Whenever possible, checks of plant operations are carried out over extended periods of time, at night and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The information to be collected during the detailed audit includes:

1. Sources of energy supplies (e.g. electricity from the grid or self-generation)
2. Energy cost and tariff data
3. Generation and distribution of site services (e.g. compressed air, steam, water, chilled water).
4. Process and material flow diagrams
5. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)
6. Energy consumption by type of energy, by department, by major process equipment, by end-use
7. Potential for fuel substitution, process modifications, and the use of co-generation system
8. Review of ongoing energy management procedures and energy awareness training programs.

Energy audit team should ensure that the following baseline data are collected:

- ✓ Quantity and type of raw materials
- ✓ Technology, process used and equipment used
- ✓ Capacity utilization
- ✓ Efficiencies / yield
- ✓ Percentage rejection / reprocessing
- ✓ Quantity and types of wastes
- ✓ Consumption of fuel, water, steam, electricity, compressed air, cooling water, chilled water

Energy auditor must specially interview the supervisors and equipment operators as they have information related to the equipment. Maintenance manager is often the primary person to talk about types of lighting, lamps, sizes of motors, A/c plant and electrical load and related performance problems.

Preparing Process Flow Diagram

An overview of unit operations, important process steps, material and energy use and waste generation is then assembled in the form of process flow diagram. Information from existing drawings, records and shop floor survey will help in preparing the flow chart. Simultaneously the team should identify the various inputs and output streams at each process step. **A typical example of flowchart of Penicillin-G manufacturing** is given in the Figure 4.1.

It may be noted that waste stream (Mycelium) and obvious energy wastes such as condensate drained and steam leakages have been identified in this flow chart. The audit focus will depend upon consumption of input resources, energy efficiency potential, impact of process step on entire process or intensity of waste generation / energy consumption. In case of Penicillin-G manufacturing, the unit operations such as germinator, pre-fermentor, fermentor and extraction are the major energy conservation potential areas identified.

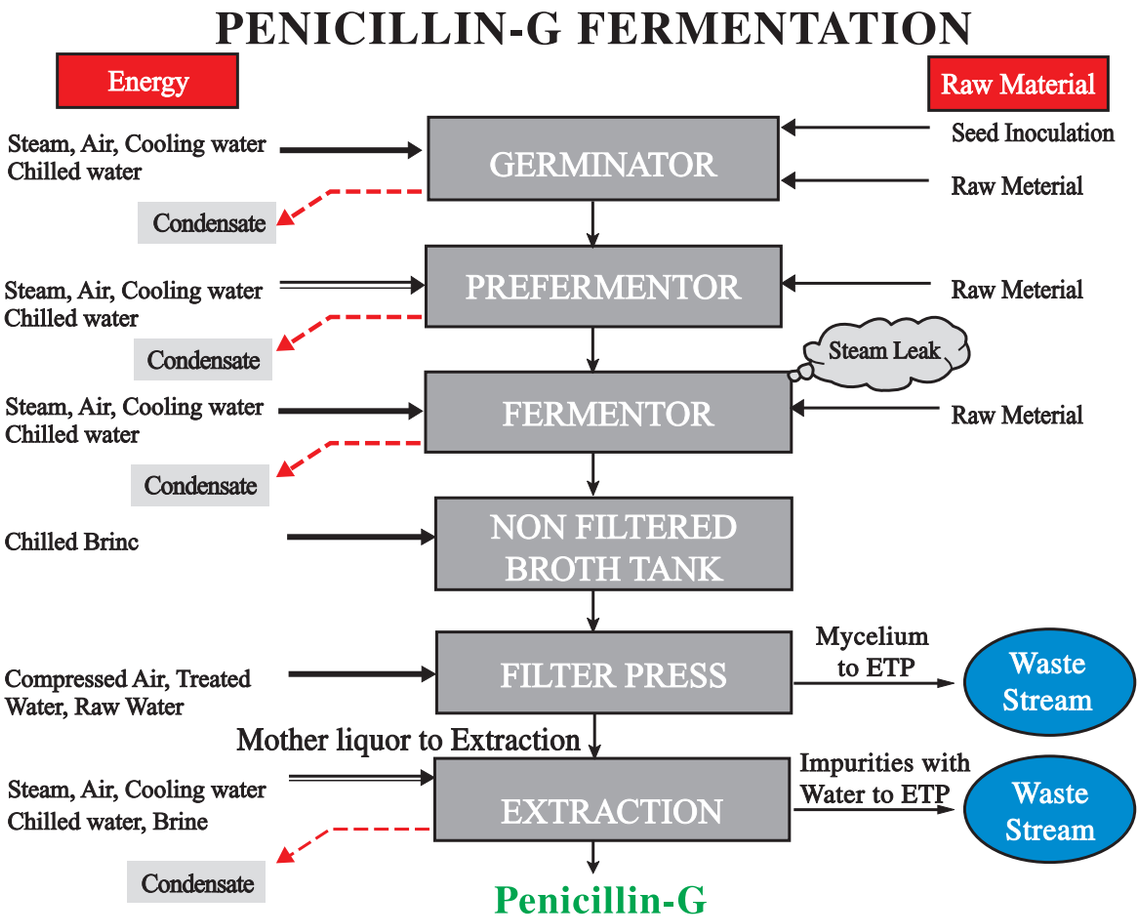

Figure 4.1 Flow Chart for Penicillin-G Manufacture

Identification of ENCON Opportunities

Fuel substitution: Identifying the appropriate fuel for efficient energy conversion

Energy Generation: Identifying efficiency opportunities in energy conversion equipment/utility such as feasibility for high efficient DG sets, optimal loading of DG sets, boiler optimization - minimum excess air combustion with boilers / thermic fluid heating, optimising existing efficiencies, efficient energy conversion equipment, biomass gasifiers, Cogeneration etc.

Energy Distribution: Identifying efficiency opportunities in electrical systems such as transformers, cables, switchgears and power factor improvement in electrical systems and chilled water, cooling water, hot water, compressed air, etc.

Energy Usage by Processes: This is where the major opportunity for improvement lies and many of them are hidden. Process analysis is a useful tool for process integration measures.

Technical and Economic Feasibility

The technical feasibility should address the following issues:

- Technology availability, space, skilled manpower etc
- The impact of energy efficiency measure on safety, quality, production or process.
- Reliability, service issues, maintenance requirements and spares availability

The Economic viability often becomes the key parameter for the management acceptance. The economic analysis can be conducted by using Pay back method, Internal Rate of Return method, Net Present Value method etc. For low investment short duration measures, which have attractive economic viability, payback method is sufficient. A sample worksheet for assessing economic feasibility is provided below:

Worksheet for Economic Feasibility

Name of the Energy Efficiency Measure		
1. Investment	2. Annual Operating costs	3. Annual Savings
1. Equipment 2. Civil works 3. Instrumentation 4. Auxiliaries	1. Cost of capital 2. Maintenance 3. Manpower 4. Energy 5. Depreciation	1. Thermal energy 2. Electrical energy 3. Raw materials 4. Waste disposal
Net Savings /year = Annual savings – Annual operating costs **Payback period in months = Investment / Net Savings /year x 12**		

Classification of ENCON Measures

The potential energy saving measures (ENCON) may be classified into three categories:

(a) Low cost – high return

(b) Medium cost – medium return

(c) High cost – high return

Normally the low cost – high return projects receive priority. Other projects have to be analyzed, engineered and budgeted for implementation in a phased manner, Projects relating to equipment and process changes almost always involve high costs coupled with high returns, and required careful scrutiny before funds can be committed. They are complex and need long lead times before they can be implemented. Refer Table 4.1 for project priority guideline.

Table 4.1 Project Priority Guideline			
Priority	**Economical Feasibility**	**Technical Feasibility**	**Risk / Feasibility**
A- good	Well defined and attractive	Existing technology adequate	No Risk/ Highly feasible
B-May be	Well defined and only marginally acceptable	Existing technology may be updated, lack of confirmation	Minor operating risk/ May be feasible
C-Held	Poorly defined and marginally unacceptable	Existing technology is inadequate	Doubtful
D-No	Clearly not attractive	Need major breakthrough	Not feasible

Energy Audit Report

The length and detail of energy audit report will depend upon the facility audited. The report should begin with an executive summary that provides the management of the audited facility with brief synopsis of the total savings and highlight of each energy saving measure. Executive summary should be tailored to non-technical personnel. The reader who understands the report is more likely to implement the recommended ENCON measures.

The main report should start with general description of the process or facility. Then annual energy consumption and bills should be presented with tables and graphs. This should be followed by description of energy inputs and outputs by major department or by major process and evaluation of efficiency of each step in the process. Then recommended ENCON measures should be presented with calculations for cost and benefits along with expected payback on any capital investment.

The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require high investments.

Regardless of the audience for the audit report, it should be written in a clear, concise and easy to understand format and style.

Report on

DETAILED ENERGY AUDIT

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5.7 Refrigeration system performance
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5.9 Electric motor load analysis
5.10 Lighting system

6.0 Energy Conservation Options and Recommendations
6.1 List of options in terms of no cost, low cost, medium cost and high cost, annual energy savings and payback
6.2 Implementation plan for energy saving measures/Projects

ANNEXURE
Al. List of instruments
A2. List of Vendors and Other Technical details

The following worksheets (refer Table 4.2 & Table 4.3) can be used as guidance for energy audit assessment and reporting in Executive Summary. Table 4.4 shows the reporting format for energy conservation recommendations in the main report.

Table 4.2 Summary Of Energy Saving Recommendations

S.No.	Energy Saving Recommendations	Annual Energy (Fuel & Electricity) Savings (kWh/MT or kL/MT)	Annual Cost Savings (Rs. Lakhs)	Capital Investment (Rs. Lakhs)	Simple Payback Period
1					
2					
3					
4					
Total					

Table 4.3 Types and Priority of Energy Saving Measures

	Type of Energy Saving Options	Annual Electricity / Fuel Savings	Annual Savings	Priority
		kWh/MT or kJ/MT	(Rs. Lakhs)	
A	No Investment (Immediate) • Operational improvement • Housekeeping			
B	Low Investment (Short to Medium Term) • Controls • Equipment modification • Process change			
C	High Investment (Long Term) • Energy efficient devices • Product modification • Technology change			

Phase III-Post Audit Phase

On completion of energy audit, energy action plan should be prepared. The energy action plan list the ENCONs which should be implemented first, and suggest an overall implementation schedule. Energy audit is incomplete without monitoring and its associated feedback. Monitoring consist of collecting and interpreting data. The data to be collected depends upon goals chosen in the energy action plan. Electrical power consumption and fuel consumption must be evaluated and monitored. The monitoring

data should provide direct feedback to those most able to implement the changes. Often additional instruments should be installed in various departments in addition to main metering.

Monitoring should result in more action. Good practices should be replicated. If the gap between planned objectives and actual achievements is large, reasons should be analyzed and new objectives, new actions should be initiated and results should be monitored. In this way, analysis, action and monitoring are a cyclic process.

Table 4.4 Reporting Format for Energy Conservation Recommendations		
A: Title of Recommendation	:	**Combine DG set cooling tower with main cooling tower**
B: Description of Existing System and its Operation	:	Main cooling tower is operating with 30% of its capacity. The rated cooling water flow is 5000 m3/ hr. Two cooling water pumps are in operation continuously with 50% of its rated capacity. A separate cooling tower is also operating for DG set operation continuously.
C: Description of Proposed System and its Operation	:	The DG Set cooling water flow is only 240 m3/h. By adding this flow into the main cooling tower will eliminate the need for a separate cooling tower operation for DG set, besides improving the %loading of main cooling tower. It is suggested to stop the DG set cooling tower operation.
D: Energy Saving Calculations		
Capacity of main cooling tower	=	5000 m^3/ hr
Temp across cooling tower (design)	=	8 ^oC
Present capacity	=	3000 m^3/hr
Temperature across cooling tower (operating)	=	4 ^oC
% loading of main cooling tower	=	(3000 x 4) / (5000 x 8) = 30%
Capacity of DG Set cooling tower	=	240 m^3/hr
Temp across the tower	=	5 ^oC
Heat Load (240 x 1000 x 1 x 5)	=	1200,000 kcal/hr
Power drawn by the DG set cooling tower		
No of pumps and its rating	=	2 Nos x 7.5 kW
No of fans and its rating	=	2 Nos x 22 kW
Power consumption@ 80% load	=	(22 x2 +7.5 x2) x.80 = 47 kW
Additional power required for main cooling tower for additional water flow of 240m^3/h (66.67 l/s) with 6 kg/cm^2	=	(66.67 x 6) / (102 x 0.55) = 7 kW
Net Energy Savings	=	47 – 7 = 40 kW
E: Cost Benefits		
Annual Energy Saving Potential	=	40 kW x 8400 hr = 3,36,000 Units/Year
Annual Cost Savings	=	3,36,000 x Rs.4.00 = Rs.13.4 Lakh per year
Investment (only cost of piping)	=	Rs 1.5 Lakhs
Simple Payback Period	=	**Less than 2 months**

4.5 Understanding Energy Costs

Contrary to common belief, energy costs are not a fixed overhead, there is often a huge potential for making savings. Understanding energy cost is vital factor for awareness creation and saving calculation. In many industries sufficient meters may not be available to measure all the energy used. In such cases, invoices for fuels and electricity will be useful. The annual company balance sheet is the other sources where fuel cost and power are given with production related information.

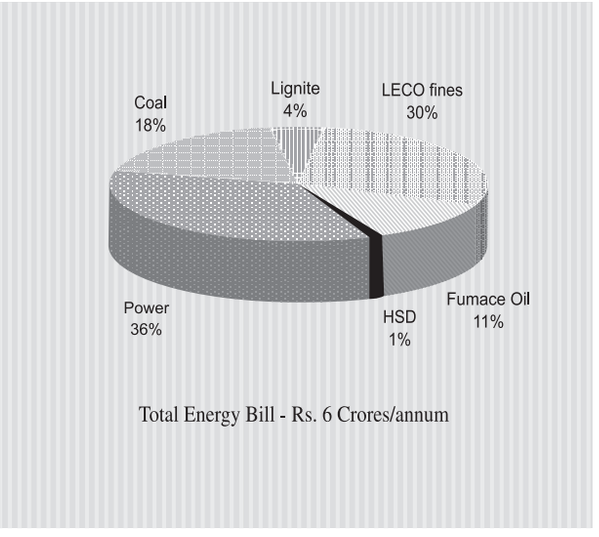
Energy invoices can be used for the following purposes:

- They provide a record of energy purchased in a given year which gives a baseline for future reference
- Energy invoices may indicate the potential for savings when related to production requirements or to air conditioning requirements/space heating etc.
- When electricity is purchased on the basis of maximum demand tariff
- They can suggest where savings are most likely to be made.
- In later years invoices can be used to quantify the energy and cost savings made through energy conservation measures.

Fuel Costs

A wide variety of fuels are available for thermal energy supply. Some of the fuels are listed below:

- Fuel oil
- Low Sulphur Heavy Stock (LSHS)
- Light Diesel Oil (LDO)
- Liquefied Petroleum Gas (LPG)
- Coal
- Lignite
- Wood etc.



Total Energy Bill - Rs. 6 Crores/annum

Understanding fuel cost is fairly simple and it is purchased in Tons or Kiloliters. Availability, cost and quality are the main three factors that should be considered while purchasing. The following factors should be taken into account during procurement of fuels for energy efficiency and economics.

- Price at source, transport charge, type of transport
- Quality of fuel (contaminations, moisture etc)
- Energy content (calorific value)

Power Costs

Electricity price in India not only varies from State to State, but also city to city and consumer to consumer though it does the same work everywhere. Many factors are involved in deciding final cost of purchased electricity such as:

- Maximum demand charges, kVA
  (i.e. **How fast** the electricity is used?)
- Energy Charges, kWh
  (i.e. **How much** electricity is consumed?)
- TOD Charges, Peak/Non-peak period
  (i.e. **When** electricity is utilized ?)
- Power factor Charge, P.F
  (i.e., **Real power use versus Apparent power use factor**)
- Other incentives and penalties applied from time to time
- High tension tariff and low tension tariff rate changes
- Slab rate cost and its variation
- Type of tariff clause and rate for various categories such as commercial, residential, industrial, Government, agricultural, etc.
- Tariff rate for developed and underdeveloped area/States
- Tax holiday for new projects

4.6 Benchmarking

Benchmarking forms the basis for monitoring and target setting

Benchmarking can be a useful tool for understanding energy consumption patterns in an industrial sector and for taking measures to improve energy efficiency. Energy benchmarking for industry is a process in which the energy performance of an individual plant or an entire sector of similar plants is compared against a common metric that represents 'standard' or 'optimal' performance. It may also entail comparing the energy performance of a number of plants against each other.

Since benchmark tool is used for comparison across a number of plants or sectors, there are two important features they should have. First, because they are applied to plants or sectors of different sizes and outputs, the metric used should be common irrespective of plant size. The most common metric used is *energy intensity* which measures *'energy use per unit of output'*. Second, the tool should be used in a wide range of facilities so as to compensate for differences in production at similar facilities.

Industrial Benchmarking Programs

There are three approaches for energy benchmarking. The first approach is to evaluate an entire industrial sector, such as iron and steel, aluminum, cement, etc. This evaluation is used to answer the following questions: How well is this sector performing compared to how it would perform using the best available

technologies? How well is it performing compared to the same sector in other countries? Has the sector been improving over time?

The second approach is the comparison of individual plants within a sector. A benchmark-type indicator is calculated for all the facilities within a sector so that they can be compared on even terms. This evaluation can answer the following questions: What is the state-of-the-art performance in this given sector? How does my plant compare against the state-of-the-art? How does it compare against the majority of other plants in the sector? In developing benchmarks at the level of individual plants, the issue of proprietary data becomes important. Individual companies are very reluctant to disclose information about their production processes, particularly if it will be released to their competitors. It is important that the indicators developed are general enough not to reveal any proprietary information and that a credible system is established that encourages plants to trust the process.

External benchmarking relates to inter unit comparison across a group of similar units to identify best practices. However, it would be important to ascertain similarities, as, otherwise, findings can be grossly misleading. Few comparative factors which need to be carefully looked into while external benchmarking extremely are:

- Scale of operation
- Vintage of technology
- Raw material specifications and quality
- Product specifications and quality

The third approach for energy benchmarking that has been seen widely in recent years is for large companies to set themselves energy efficiency goals by using historical best performance as benchmark. Companies use this approach to set targets for reducing energy use by certain percentages over given time frames. Companies do not need to reveal any proprietary information, since the benchmarking is done internally.

Steps in energy conservation benchmarking are summarized below:

- Identify the best available technology for the individual process units.
- Collect information to thoroughly understand the process and identify key/controlling parameters.
- Determine the performance of the process unit.
- Analyse the gap between the existing and the benchmark for the key controlling parameters.
- Set targets or benchmarks, keeping constraints in view, and implement improvements based on the findings

The benchmark parameters for various sectors are given as follows:

- Gross Production Related

  kWh/MT clinker or cement produced (Cement plant)

  kWh/kg yarn produced (Textile unit)

kWh/MT, kcal/kg paper produced (Paper plant)

kcal/kWh Power produced (Heat rate of a power plant)

Million Calories/MT Urea or Ammonia (Fertilizer plant)

kWh/MT of liquid metal output (in a foundry)

- Equipment / Utility Related

kWh/ton of refrigeration (on Air-conditioning plant)

% thermal efficiency of a boiler plant

% cooling tower effectiveness in a cooling tower

kWh/Nm^3 of compressed air generated

kWh/litre in a diesel power generation plant.

While such benchmarks are referred to, related crucial process parameters need to be stated for meaningful comparison among similar industries. For instance, in the above case:

- For a cement plant – type of cement, blaine number (fineness) i.e. Portland and process used (wet/dry) are to be reported alongside kWh/MT figure.
- For a textile unit – average count, type of yarn i.e. polyester/cotton, is to be reported along side kWh/kg figure.
- For a paper plant – paper type, raw material (recycling extent), GSM quality are some important factors to be reported along with kWh/MT, kcal/kg figures.
- For a power plant / cogeneration plant – plant % loading, condenser vacuum, inlet cooling water temperature, would be important factors to be mentioned alongside heat rate (kcal/kWh).
- For a fertilizer plant – capacity utilization(%) and on-stream factor are two inputs worth comparing while mentioning specific energy consumption
- For a foundry unit – melt output, furnace type, composition (mild steel, high carbon steel/cast iron etc.) raw material mix, number or power trips could be some useful operating parameters to be reported while mentioning specific energy consumption data.
- For an A/C plant – parity of chilled water temperature level is crucial while comparing kW/TR.
- For a boiler plant – fuel quality, type, steam pressure, temperature, flow are useful comparators alongside thermal efficiency and more importantly, whether thermal efficiency is on gross calorific value basis or net calorific value basis or whether the computation is by direct method or indirect heat loss method, mean a lot in benchmarking exercise for meaningful comparison.
- For a cooling tower - Effectiveness – ambient air wet/dry bulb temperature, relative humidity, air and circulating water flows are required to be reported to make meaningful sense.
- For a compressed air system - specific power consumption – is to be compared at similar inlet air temperature and pressure of generation.
- Diesel power plant performance – is to be compared at similar loading %, steady run condition.

4.7 Energy Performance

Plant Energy Performance

Plant energy performance (PEP) is the measure of whether a plant is now using more or less energy to manufacture its products than it did in the past: a measure of how well the energy management programme is doing.

Plant energy performance monitoring compares plant energy use of a reference year and the subsequent years considering production output to determine the improvement (or deterioration) that has been made.

However, since the plants' production output varies from year to year, it has significant impact on plant's energy use. For a meaningful comparison it is necessary to determine the energy that would have been required to produce current year's production output had the plant operated in the same way as it did during the reference year. This calculated value can then be compared with the actual value to determine the improvement or deterioration that has taken place since the reference year.

Production Factor

Production factor is the ratio of production in the current year to that in the reference year.

$$\text{Production factor} = \frac{\text{Current year's production}}{\text{Reference year's production}}$$

Production factor is used to determine the *energy* that would have been required to produce this year's production output if the plant had operated in the same way as it did in the reference year.

Reference Year Equivalent Energy Use

The *reference year's equivalent energy use (or reference year equivalent)* is the energy that would have been used to produce the current year's production output.

The reference year equivalent is obtained by multiplying the reference year energy use by the production factor (obtained above)

$$\text{Reference year equivalent} = \text{Reference year energy use} \times \text{Production factor}$$

Plant Energy Performance is the improvement or deterioration from the reference year. It is a measure of plant's energy progress.

$$\text{Plant energy performance} = \frac{\text{Reference year equivalent} - \text{Current year's energy}}{\text{Reference year equivalent}} \times 100$$

The energy performance is the measure of energy saved at the current rate of use compared to the reference year rate of use. The greater the improvement, the higher the number will be.

Plant energy performance (PEP) is the starting point for evaluating energy performance. It does not require detailed calculations of the energy used by every place of equipment, the energy use of every process or the energy use of buildings. It utilizes the most effective measure of energy savings, the actual measurement of energy consumption compared to production output. Yearly comparisons minimize seasonal effects.

Sometimes, once a plant has started measuring yearly energy performance, management wants more frequent performance information in order to monitor and control energy use on an on-going basis. In such cases PEP can just as easily be used for monthly reporting as yearly reporting.

4.8 Matching Energy Usage to Requirement

Mismatch between equipment capacity and user requirement often leads to energy inefficiencies due to part load operations, wastages etc.

The designer always considers safety margins while laying specifications for new equipment leading to oversized equipment. This presents opportunity for energy manager for matching the equipment capacity with user requirement. Some examples for matching energy usage to requirements are listed below:

- Eliminating throttling of a pump by impeller trimming, installing variable speed drives and resizing pump
- Eliminating damper operations in fans by impeller trimming, installing variable speed drives, pulley diameter modification for belt drives, fan resizing for better efficiency.
- Moderating chilled water temperature as per process chilling needs
- Recovering energy lost in control valve pressure drops with back pressure turbine adoption
- Adopting of task lighting in place of less effective area lighting

4.9 Maximizing System Efficiencies

Once the energy usage and sources are matched properly, the next step is to operate the equipment efficiently through best operation and maintenance practices and adoption of best available technology, if feasible. Some examples are:

- Eliminating steam leakages by using appropriate steam traps
- Maximising condensate recovery
- Adopting combustion controls for maximizing combustion efficiency
- Replacing pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy conservation equipment, wherever significant energy efficiency margins exist
- Ensuring rated electrical parameters at the motor terminals

4.10 Optimising Input Energy Requirements

After fine-tuning the energy use practices, attention should be given for minimizing energy input requirements. The measures include:

- Maximising heat recovery from waste energy streams, to minimize purchased energy
- Adopting cogeneration plants for balancing heat and power requirements, leading to reduced energy purchases
- Adopting cost effective renewable sources of energy such as solar, wind and biomass energy

4.11 Fuel and Energy Substitution

Fuel substitution is basically substituting existing fossil fuel with more efficient and less cost/less polluting fuel such as natural gas, biogas and locally available agro-residues.

Fuel substitution has taken place in all the major sectors of the Indian economy.

Few examples of fuel substitution

- Natural gas is increasingly the fuel of choice as fuel and feedstock in the fertilizer, petrochemicals, power and sponge iron industries.
- Replacement of coal by coconut shells, rice husk etc.
- Replacement of LDO by LSHS

There are two ways to reduce energy dependency; energy conservation and substitution.

Few examples of energy substitution

- ✓ Replacement of electric heaters by steam heaters
- ✓ Replacement of steam based hot water by solar systems

Case Study: Example on Fuel Substitution

A textile process industry replaced old fuel oil fired thermic fluid heater with agro fuel fired heater. The economics of the project are given below:

A: Title of Recommendation	**:**	**Use of Agro Fuel (coconut chips) in place of Furnace oil in a Boiler**
B: Description of Existing System and its operation	**:**	A thermic fluid heater with furnace oil currently. In the same plant a coconut chip fired boiler is operating continuously with good performance.
C: Description of Proposed system and its operation	**:**	It was suggested to replace the oil fired thermic fluid heater with coconut chip fired boiler as the company has the facilities for handling coconut chip fired system.

D: Energy Saving Calculations

Old System

Type of fuel firing	**:**	**Furnace Oil Fired Heater**
GCV	:	10,200 kcal/kg
Avg. Thermal Efficiency	:	82%
Heat Duty	:	15 lakh kcal / hour
Operating Hours	:	25 days x 12 month x 24 hours = 7,200 hrs.
Annual Fuel Cost	:	Rs.130 lakh (7200 x 1800 Rs./hr.)

Modified System

Type of fuel saving	**=**	**Coconut Chips Fired Heater**
GCV	=	4200 kcal/kg
Average Thermal Efficiency	=	72 %
Heat Duty	=	15 lakh kcal / hour
Annual Operating Cost	=	7200 x 700 Rs./hr = 50 lakh
Annual Savings	=	130 - 50 = Rs.80 lakh .
Additional Auxiliary Power + Manpower Cost	=	Rs. 10 lakh
Net Annual Saving	=	Rs. 70lakh
Investment for New Coconut Fired heater	=	Rs.35 lakh
Simple payback period	**=**	**6 months**

4.12 Instruments and Metering For Energy Audit

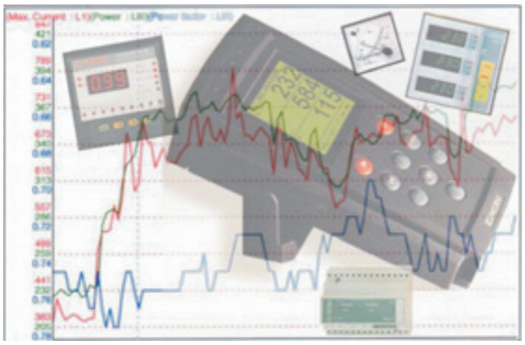
The requirement for an energy audit is to identify and quantify where energy is being used necessitates measurements. These measurements require the use of instruments. The basic instruments used in energy audit work are listed below. These instruments are portable, durable, easy to operate and relatively inexpensive.

Key Performance Parameters for Energy Audit

Basic Electrical Parameters in AC & DC systems – Voltage (V), Current (I), Power factor, Active power (kW), Maximum demand (kVA), Reactive power (kVAr), Energy consumption (kWh), Frequency (Hz), Harmonics, etc.

Parameters of importance other than electrical such as Temperature and Heat Flow, Radiation , Air and Gas Flow, Liquid Flow, RPM , Air Velocity, Noise and Vibration, Dust Concentration, TDS, PH, Moisture Content, Relative Humidity, Flue Gas Analysis – CO_2, O_2, CO, SO_x, NO_x, Combustion Efficiency etc.

Some of the instruments commonly used in an energy audit are described as follows.



Electrical Measuring Instruments:

These are instruments for measuring major electrical parameters such as KVA, KW, PF, Hertz, KVAr, Amps and Volts. In addition some of these instruments also measure harmonics.

These instruments are applied on-line i.e. on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.

Some precautions and safety measures:

To avoid short circuits and potentially life-threatening hazards, never attach the clamp to a circuit that operates at more than the maximum rated voltage, or over bare conductors.

While using the instrument, use rubber hand gloves, boots, and a safety helmet, to avoid electrical shocks, and do not use the instrument when hands are wet.

Fyrite:

In this, a hand bellow pump draws the flue gas sample into the solution inside the fyrite. Thereafter, a chemical reaction changes the liquid volume that reveals the amount of gas percentage. Oxygen or CO_2 can be read from the scale. The FYRITE employs the well-known "Orsat method of volumetric analysis" using chemical absorption of a sample gas such as carbon dioxide or oxygen. The reagent used to absorb carbon dioxide (CO_2) is potassium hydroxide (dyed red), and chromous chloride (blue) is the absorbent for oxygen (O_2). The unique feature of the FYRITE is that the absorbing fluid is also used as the indicating fluid so that one vessel takes the place of both measuring burette and absorption pipette.

Fuel Efficiency Monitor:

This measures Oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.

Combustion Gas Analyzer:

This instrument has in-built chemical cells which measure various gases such as CO_2, CO, NO_X, SO_X etc.

Gas analyzers are flexible in what must be measured depending on the requirements of the customer/user.

They have specific sensors sealed inside the equipment that can be changed to measure the different components in the gas. But because a maximum of two sensors can be connected, only two or three parameters can be measured at one time.

It is light and easier to handle compared to the fuel efficiency monitor.

Manometer with Pitot Tube:

Digital flexible membrane manometer is used for measuring pressures in air ducts carrying exhaust flue gases (boiler, furnaces), or air from fans and blowers.

- To measure pressure in air pipes, manometers must be used in combination with a pitot tube
- Attach flexible rubber tubes to the inlet and outlet probes of the manometer. Tighten these to ensure that there is no leakage of air.
- Attach these two tubes to the ends of the pitot tube
- Make a 6-cm monitoring hole in the duct or pipeline
- Insert the pitot tube into the monitoring hole

	Contact Thermometer: These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature a leaf type probe is used with the same instrument.
	Non Contact Infrared Thermometer: Infrared thermometers calculate the amount of thermal radiation (infrared radiation) emitted from the object. By knowing the emissivity of the object and the amount of infrared energy emitted by the object, the object's temperature can be determined. With the help of infrared thermometers, temperatures of the objects placed in hazardous or hard-to-reach places or other situations can be determined. The most common design of a IR thermometer consists of a lens to focus the infrared energy on to a detector. The detector changes the energy to an electrical signal that can be shown in units of temperature after being corrected for ambient temperature variation.
	Ultrasonic Flow Meter: This is one of the popular means of non-contact flow measurement. There are two main types of ultrasonic flow meters: Transit time and Doppler. Transit time ultrasonic meters have both a sender and a receiver. They send two ultrasonic signals across a pipe: one traveling with the flow and one traveling against the flow. The ultrasonic signal traveling with the flow travels faster than a signal traveling against the flow. The ultrasonic flow meter measures the transit time of both signals. The difference between these two timings is proportional to flow rate. Transit time ultrasonic flow meters usually monitor clean liquids. Doppler ultrasonic flow meters measure dirty liquids. They compute flow rate based on a frequency shift that occurs when their ultrasonic signals reflect off particles in the flow stream.

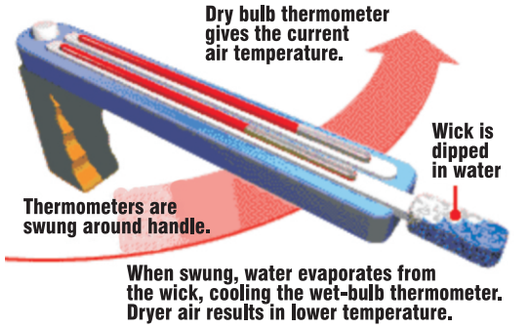
Tachometer

Stroboscope

Speed Measurements:

In any audit exercise speed measurements are critical as they may change with factors such as frequency, belt slip, loading, etc. A simple tachometer is a contact type instrument, which can be used where direct access is possible.

More sophisticated and safer ones are non contact instruments such as stroboscopes. A stroboscopic light source provides high-intensity flashes of light, which can be caused to occur at a precise frequency. When this light source is made to fall on an object with periodic motion it appears that the motion is slowed down, or stopped when both the frequencies bear a definite relationship. A stroboscope uses this principle for measurement of RPM.



Psychrometer:

A sling psychrometer - consists of two thermometers mounted together with a handle. One thermometer is ordinary and measures the dry bulb temperature. The other has a wet cloth wick, over its bulb and is called a wet-bulb thermometer. When a reading is to be taken the psychrometer is whirled around. The water evaporates from the wick, cooling the wet-bulb thermometer. Then the temperatures of both thermometers are read. If the surrounding air is dry, more moisture evaporates from the wick, cooling the wet-bulb thermometer more, so there is a greater difference between the temperatures of the two thermometers. By using these temperatures the humidity is computed.

Lux Meters:

A light sensitive cell measures the incident light (all light in the visible spectrum is measured) and evaluates that against the human daylight sensitivity curve. The resulting value is the measurement result in lux. This works well but it requires a different correction factor for every light spectrum.

The much more expensive lux meters with one cell are optimized and tuned with optical filters and lenses such that the sensitivity of this set of lenses and the cell itself directly matches the eye's light sensitivity curve (so only one correction value needed for light of any spectral content).

Smart Energy Meters

The term smart meter usually refers to electric meters which keep detailed statistics on usage, but it can be used for fuels or water applications as well performing the same job. The primary purpose of smart meters is to provide information on how end users use their electricity on a real-time basis. The smart energy meters use a wireless communication to help track the electricity consumption and thus save both electricity and money. It can be easily installed and gives an accurate reading of electricity consumption which can also be monitored / controlled through mobile or internet.

	Thermography Infra-red thermal monitoring and imaging (non-contact type) measures thermal energy radiation from hot/cold surfaces of an object and provides input for assessing health of equipment and predictive maintenance. The thermal camera unit converts electromagnetic thermal energy (IR) radiated from an object into electronic video signals. These signals are amplified and transmitted via interconnected cable to a display monitor where the resulting image is analysed and interpreted for hot/cold spots.

4.13 Bureau of Energy Efficiency (the manner and intervals of time for conduct of energy audit) Regulations, 2008

Intervals of time for conduct of energy audit

(1) Every designated consumer shall have its first energy audit conducted, by an accredited energy auditor within 18 months of the notification issued by the Central Government

(2) The interval of time for conduct and completion of subsequent energy audits shall be three years with effect from the date of submission of the previous energy audit report by the accredited energy auditor to the management of the designated consumer.

Manner of energy audit

1. Verification of data of energy use

a) Verify the information submitted to the designated agency under the Energy Conservation (the form and manner for submission of report on the status of energy consumption by the designated consumers) Rules, 2007 for the previous two years

b) Establish specific energy consumption for the year referred to in clause (a);

c) Disaggregate the energy consumption data and identify major energy using equipment, processes and systems.

2. Scope of energy audit

The accredited energy auditor jointly with the energy manager of the designated consumer shall-

(a) Develop a scope of work for the conduct of energy audit with a view to ensuring adequate coverage in terms of the share of total energy use

(b) Select energy intensive equipment or processes for energy auditing;

(c) Agree on best practice procedures on measuring the energy efficiency performance of selected equipment and on methodology to estimate energy performance and energy savings;

(d) Collect energy consumption, and production data for the equipment and processes covered within the scope of energy audit, operating data, and schedule of operation, non proprietary process flow charts, and production level disaggregated by product, if applicable, and other related historical data essential by the accredited energy auditor for achieving the purpose of energy audit.

3. Monitoring and analysis of the use of energy data for energy audit

The accredited energy auditor shall-

(a) Verify the accuracy of the data collected in consultation with the energy manager as per standard practice to assess the validity of the data collected;

(b) Analyse and process the data with respect to-

(i) Consistency of designated consumers' data monitoring compared to the collected data;

(ii) Recommendations to reduce energy consumption and improve energy efficiency;

(iii) Summary overview of energy consumption in plant by fuel type and by section;

(c) Conduct equipment energy performance measurements with due diligence and caution.

4. Preparation of recommendations on energy saving measures, their cost benefit analysis

The accredited energy auditor having regard to the overall efficiency of the production process, techno-economic viability of energy saving measures, site conditions and capacity of the designated consumer to invest for their implementation, shall prepare a list of recommendations to save energy and the list shall include:

(a) A brief description of each recommended measure

(b) The estimated energy saving as well as energy cost reduction potential over a reasonable technical or economic life of the measure;

(c) Any known or expected technical risks associated with each measure;

(d) A preliminary assessment of the financial attractiveness of each measure or assessment of the maximum investment feasible based on the estimated energy cost saving potential over the life of the measure;

(e) Tabulated summary of recommendations listed as per their implementation schedule (short, medium and long term);

(f) Where different alternatives for implementation of an energy efficiency measure are available, the accredited energy auditor shall examine and discuss such options and recommend the techno-financially better option;

(g) Where the installation or implementation of any recommended energy saving measure affects procedures for operation and maintenance, staff deployment and the budget, the recommendation shall include discussion of such impacts including their solutions.

Prioritization and preparation of action plan

(1) The accredited energy auditor jointly with the energy manager shall select from the energy audit report such recommended measures which in the opinion of the designated consumer are technically viable, financially attractive and within its financial means, prioritise them and prepare plan of action for their implementation. This action plan shall include-

(a) Preparation of detailed techno-economic analysis of selected measures;

(b) A monitoring and verification protocol to quantify on annual basis the impact of each measure with respect to energy conservation and cost reduction for reporting to Bureau and the concerned State designated agency;

(c) A time schedule agreed upon by the designated consumer of selected measures taking into consideration constraints such as availability of finance and availability of proposed equipment.

(2) The accredited energy auditor based on the activities undertaken under sub-regulation (4) of regulation 4 and regulation 5 shall submit a report in Form 2 to the management of designated consumer.

(3) The accredited energy auditor shall evaluate the implementation of each recommended energy saving measure in the previous audit report and submit a report in Form 3 to the management of the designated consumer.

Structure of the energy audit report

(1) The energy audit report structure shall be jointly decided by the accredited energy auditor and designated consumer.

(2) The energy audit report shall highlight, details of specific energy consumption, list of recommendations to reduce energy consumption and costs, monitoring and evaluation of impact of selected measures and conclude with certification by accredited energy auditor stating that -

a) The data collection has been carried out diligently and truthfully.a)

b) All data monitoring devices are in good working condition and have been calibrated or certified by approved or authorized agencies and no tempering of such devices have occurred.

c) All reasonable professional skill, care and diligence have been taken in preparing the energy audit report and the contents thereof are a true representation of the facts.

d) Adequate training provided to personnel involved in daily operations after implementation of recommendations.

e) The energy audit has been carried out in accordance with the Bureau of Energy Efficiency (the manner and intervals of time for conduct of energy audit) Regulation, 2008.

(3) The accredited energy auditor shall highlight the strengths and weaknesses of the designated consumer in the management of energy and energy resources in the energy audit report and recommend necessary action to improve upon method of reporting data, energy management system in detail along with their underlying rationale, and improving energy efficiency and reducing energy consumption of the designated consumer.

(4) The accredited energy auditor shall sign the energy audit report under the seal of its firm giving all the accreditation details along with details of manpower employed in conducting the energy audit.

(5) The energy audit report shall include a work schedule sheet duly signed by accredited energy auditor and energy manager of the designated consumer.

Solved Example:

An Energy Manager in a factory has gathered following data to arrive at the Plant Energy Performance.

Reference Year (2009) energy use	: 12 million kcal
Production Factor (PF) for the current year (2010)	: 0.9
Current year's energy	: 11 million kcal

What is the Plant energy Performance (PEP) of the factory for the year 2010? State your inference.

Ans:

Reference year equivalent energy = Reference year energy use * P.F

$$= 12 * 0.9 = 10.8 \text{ Mkcal}$$

$$\text{Plant Energy Performance} = \frac{(\text{Reference year equivalent} - \text{current year's energy}) * 100}{\text{Reference Year equivalent}}$$

$$= (10.8 - 11) / 10.8$$

$$= -1.85\ \%$$

Inference: Plant energy performance is marginally negative. Energy manager/plant manager has to take action to improve the performance.

QUESTIONS	
Objective Type Questions	
1.	"The judicious and effective use of energy to maximise profits and enhance competitive positions". This can be the definition of: a) energy conservation b) energy management c) energy policy d) energy Audit
2.	Role of energy manger is a) energy auditor and in charge of the finance department of the plant b) intermediate player between top management, energy and cost centres of the plant c) in charge of the captive power plant and mediator between plant and electricity boards d) as well as called production manger and project manager
3.	The objective of energy management includes a) minimising energy costs b) minimising waste c) minimising environmental degradation d) all the above
4.	The ratio of current year's production to the reference year's production is a) demand factor b) production factor c) utilisation factor d) load factor
5.	One unit of electricity is equivalent to _____ kcal heat units. a) 800 b) 860 c) 400 d) 680
6.	The benchmarking parameter for air conditioning equipment is a) kW/Ton of refrigeration b) kW/ kg of refrigerant handled c) kcal/m^3 of chilled water d) differential temperature across chiller
7.	Which instrument is used to monitor O_2, CO in flue gas? a) combustion analyzer b) power analyzer c) pyrometer d) fyrite
8.	Non contact speed measurements can be carried out by a) tachometer b) stroboscope c) oscilloscope d) speedometer
9.	Which one of the following is not considered for external benchmarking: a) scale of operation b) vintage of technology c) energy price d) quality of raw material and products
10.	Transit time method is used in which of the instruments a) lux meter b) ultrasonic flow meter c) Pitot tube d) fyrite
Short Type Questions	
S-1	Explain what is meant by targeted energy audit
S-2	Explain the major differences between preliminary energy audit and detailed energy audit
S-3	What are the areas that need to be focused during pre audit phase ?

S-4	What is meant by energy benchmarking ? How is it helpful ?
S-5	What do you understand by matching energy use to requirements ? Give three examples
Long Type Questions	
L-1	Explain the following i) Production factor ii) Reference Year Equivalent iii) Plant Energy Performance
L-2	Write short notes on i) psychrometer ii) infrared thermometer iii) stroboscope iv) pitot tube

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   www.eeca.govt.nz

   www.energyusernews.com

Chapter 5

Material and Energy Balance

Learning Objectives

In this chapter you will learn about

- Need for material and energy balance
- Understanding Sankey diagram and its uses
- How to construct a process flow diagram?
- Energy system analysis
- How to carryout material and energy balance?

5. MATERIAL AND ENERGY BALANCE

Facility as an energy system, Methods for preparing process flow, Material and energy balance diagrams.

5.1 Introduction

A material balance in its most broad definition is the application of the law of conservation of mass, which states matter is neither created nor destroyed. Matter may flow through a control volume and may be reacted to form another species, however, no matter is ever lost or gained. The same is true for energy. As with material balances, we can apply the law that energy is neither created nor destroyed, it is simply converted into another form of energy. The law of conservation of mass and energy leads to what is called a mass (material) and energy balance.

Material balances, as they pass through processing operations, can describe material quantities. If there is no accumulation, what goes into a process must come out. This is true for batch operation. It is equally true for continuous operation over any chosen time interval.

Material balances are fundamental to the control of processing, particularly in the control of yields of the products. Material balance can be determined from conceptual stage to final production stage. Initially, material balance is estimated during the planning stage of a new process or equipment. This estimate is improved while carrying out pilot scale tests related to the new process. This material balance is verified during commissioning stage and finally used as a control measure during actual production stage.

Purpose of Material and Energy Balance

- To assess the input, conversion efficiency, output and losses
- To quantify all material, energy and waste streams in a process or a system
- Powerful tool for establishing basis for improvement and potential savings

Energy balances are means for industry to examine ways of reducing energy consumption in processing because of increasing energy cost. Energy balances are used in the examination of the various stages of a process, over the whole process and even extending over the total production system from the raw material to the finished product.

5.2 Components of Material and Energy Balance

Typical components of material and energy balance for a process or unit operation is shown in Figure 5.1. It may be noted that recycle stream is shown along with input side.

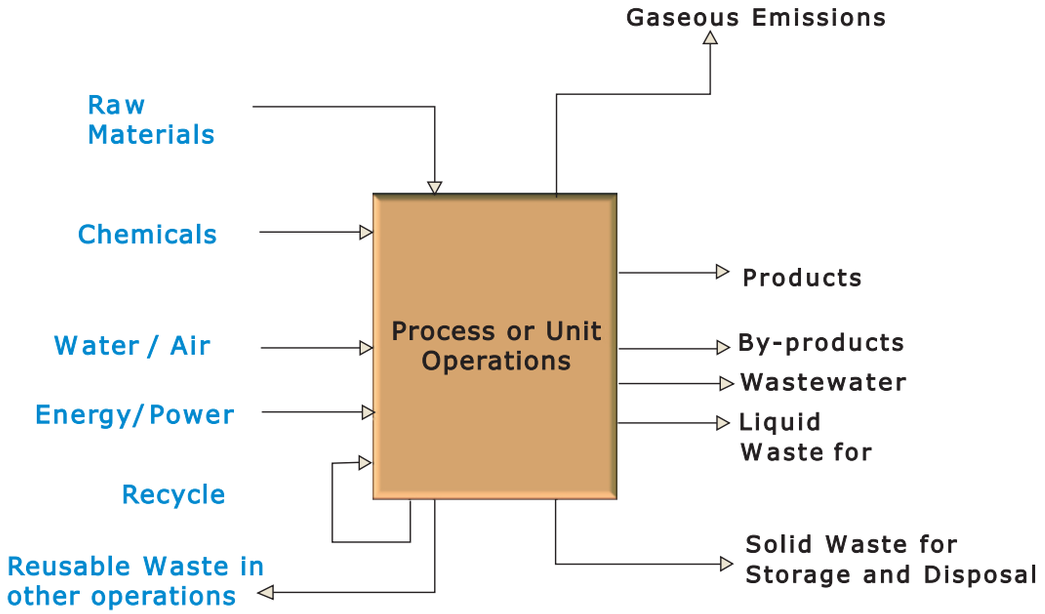


Figure 5.1 Components of Material and Energy Balance of a Process or Unit Operation

5.3 Basic Principles of Material and Energy Balance

If the unit operation, whatever its nature is seen as a whole it may be represented diagrammatically as a box, as shown in Figure. 5.2. The mass and energy going into the box must balance with the mass and energy coming out.

The law of conservation of mass leads to what is called a mass or a material balance.

Mass In = Mass Out + Mass Stored

Raw Materials = Products + Wastes + Stored Materials.

$$\Sigma m_R = \Sigma m_P + \Sigma\, m_W + \Sigma m_S$$

(Where, Σ (sigma) denotes the sum of all terms).

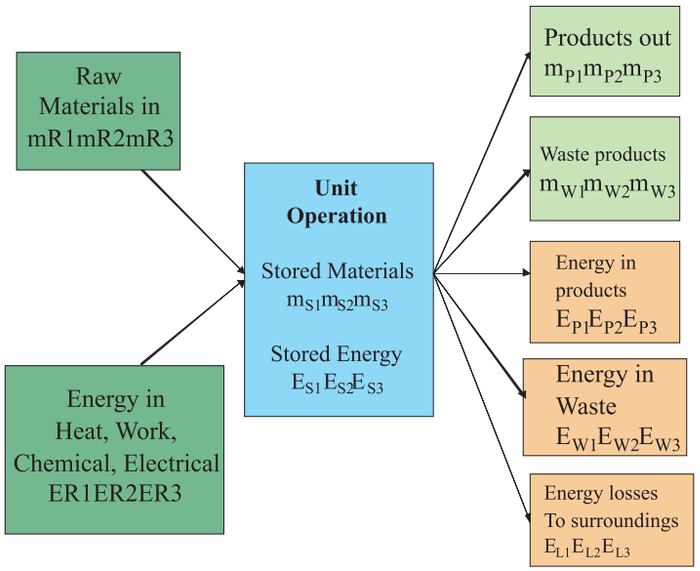


Figure 5.2 Mass and Energy Balance

$$\Sigma m_R = \Sigma m_{R1} + \Sigma\, m_{R2} + \Sigma m_{R3} \quad = \text{Total Raw Materials}$$

$$\Sigma m_P = \Sigma m_{P1} + \Sigma\, m_{P2} + \Sigma m_{P3} \quad = \text{Total Products.}$$

$\Sigma m_W = \Sigma m_{W1} + \Sigma\, m_{W2} + \Sigma m_{W3}$ = Total Waste Products

$\Sigma m_S = \Sigma m_{S1} + \Sigma\, m_{S2} + \Sigma m_{S3}$ = Total Stored Products.

If there are no chemical changes occurring in the plant, the law of conservation of mass will apply also to each component, so that for component A:

mA in entering materials = *mA* in the exit materials + *mA* stored in plant.

For example, in a plant that is producing sugar, if the total quantity of sugar (mA) going into the plant is not equalled by the total of the purified sugar (mAp) and the sugar in the waste liquors (mAw) and accumulated in the process (mAs), then there is something wrong. Sugar is either being burned (chemically changed) or else it is going unnoticed down the drain somewhere. In this case:

$$mA = (mA_P + mA_W + mA_S + mA_U)$$

Where, m_{AU} is the unknown loss and needs to be identified. So the material balance is now:

Raw Materials = Products + Waste Products + Stored Products + Losses

Where, Losses are the unidentified materials.

Just as mass is conserved, energy is conserved in process operations. The energy coming into a unit operation can be balanced with the energy coming out and the energy stored.

Energy In = Energy Out + Energy Stored

$$\Sigma E_R = \Sigma E_P + \Sigma E_W + \Sigma E_L + \Sigma E_S$$

Where,

$\Sigma E_R = E_{R1} + E_{R2} + E_{R3} + .$ = Total Energy entering with raw materials

$\Sigma Ep = E_{P1} + E_{P2} + E_{P3} + .$ = Total Energy leaving with products

$\Sigma E_W = E_{W1} + E_{W2} + E_{W3} + .$ = Total Energy leaving with waste materials

$\Sigma E_L = E_{L1} + E_{L2} + E_{L3} + .$ = Total Energy lost to surroundings

$\Sigma E_S = E_{S1} + E_{S2} + E_{S3} + .$ = Total Energy stored

Energy balances are often complicated because forms of energy can be inter-converted, for example mechanical energy to heat energy, but overall the quantities must balance.

5.4 Classification of Processes

Process can be viewed overall or as a series of units. Each unit is a unit operation that can be represented by a box as shown in Figure 5.3. Raw materials and energy go into the box and desired products, by-products, wastes and energy come out of the box. The mass in and out of a control box must be equal. The equipment within the box will make the required changes with little waste and energy as possible. There are different types of process.

A) Based on how the process varies with time

Steady-state process is one where none of the process variables change with time

Unsteady-state process is one where the process variables change with time

B) Based on how the process was built to operate

A continuous process is one that has the feed streams and product streams moving into and out of the process all the time. Examples are oil refinery, distillation process etc.

A batch process is one where the feed streams are fed to the process to get it started. The feed material is then processed through various process steps and finished products are taken out at specific times. Steps:

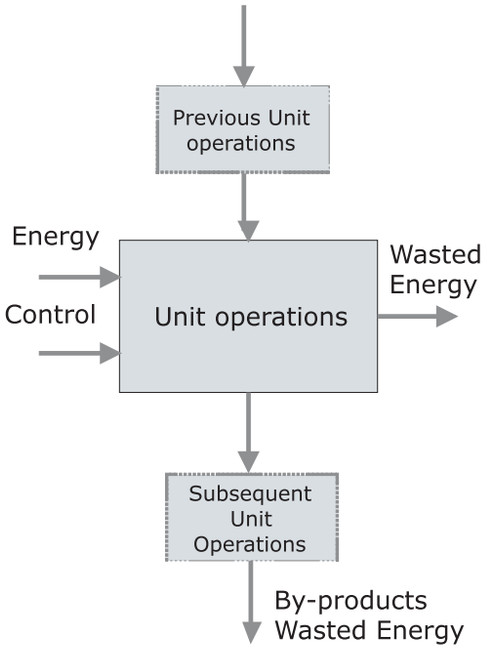


Figure 5.3 Representation of Process

- Feed is charged into vessel
- Process is started
- No mass is added or removed from vessel (process parameters are usually monitored and controlled)
- At some conditions or after fixed time, products are removed.

5.5 Material Balance

Levels of Material Balance

The material balances can be developed at various levels:

Overall Material balance: This involves input and output steams for complete plant

Section wise Material balances: This involves M&E balances to be made for each section/department/ cost centre. This would help to prioritise focus areas for efficiency improvement

Equipment-wise Material balances: Material balances for key equipment would help assess performance of equipment, which would in turn help identify energy and material losses.

The choice among the types of material balance depends on the reasons for making the balance. The major factor is the cost of the materials and so costly materials are more likely considered than cheaper ones and products more than waste materials

Material Balance Procedure

First step is to identify materials in, materials out and material stored. Next step is to consider whether materials in each category have to be treated as whole (gross material balance) or whether individual constituents in the material should be treated separately. For example, we can do material balance for dry solids alone as opposed to total material. This means separating the material into two constituents, non-water and water.

Typical steps are as follows:

a) Define basis & units: Choose a basis of calculations on quantity (mass for batch process) or flow rate (mass per hour for continuous process) of one of the process streams. Convenient Units are then chosen as mass can be expressed in various ways: weight/weight (w/w), weight/volume (w/v), molar concentration (M), mole fraction.

- The weight/weight concentration is the weight of the solute divided by the total weight of the solution and is the fractional form of the percentage composition by weight.
- The weight volume concentration is the weight of solute in the total volume of the solution. With gases, concentrations are primarily measured in weight concentrations per unit volume, or as partial pressures.
- The molar concentration is the number of molecular weights of the solute expressed in kg in 1 m^3 of the solution.
- The mole fraction is the ratio of the number of moles of the solute to the total number of moles of all species present in the solution.

b) Draw a flowchart: Establish a boundary so that the flow streams in and out can be identified. The identification and drawing up a unit operation/process is prerequisite for energy and material balance. Flow charts are schematic representation of the production process, involving various input resources, conversion steps and output and recycle streams. The process flow may be constructed stepwise i.e. by identifying the inputs / output / wastes at each stage of the process, as shown in the Figure 5.4.

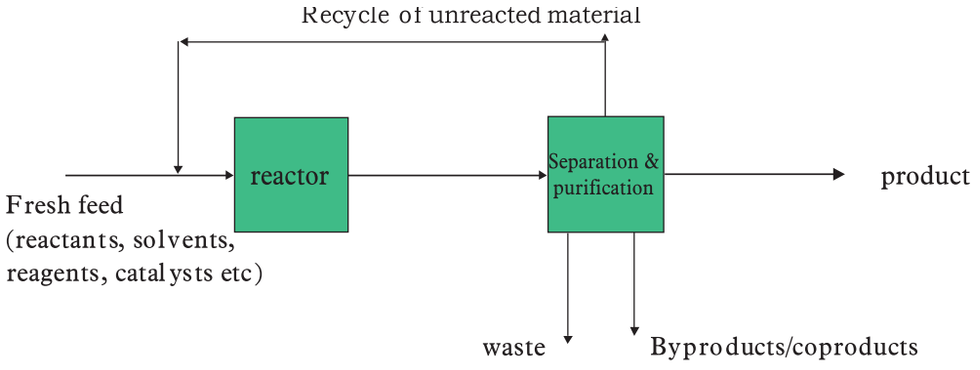


Figure 5.4 Typical Arrangement of a Process Flowchart

- **Inputs** of the process could include raw materials, water, steam, energy (electricity, etc);

- **Process Steps** should be sequentially drawn from raw material to finished product. Intermediates and any other by-product should also be represented. The operating process parameters such as temperature, pressure, % concentration, etc. should be represented.
- The flow rate of various streams should also be represented in appropriate units like m^3/h or kg/h. In case of batch process the total cycle time should be included.
- **Wastes /** by products could include solids, water, chemicals, energy etc. For each process steps (unit operation) as well as for an entire plant, energy and mass balance diagram should be drawn.
- **Output** of the process is the final product produced in the plan

c) Write Material Balance Equations: The following examples are illustration for writing the material balance equations

Example 5.1

A solution which contains 10% solids is mixed with 25% solid solution. A single output which is 20% solid is removed. If the 10% solution enters at 5.0 kg/s, what are the other rates? (Assume no accumulation)

Solution

Basis:

Solution A (INPUT) = 5 kg/s
Solution B (INPUT) = x kg/s
Solution C (OUTPUT) = y kg/s
Therefore A + B = C
5 + X = Y…… EQ -1

Since solution A contains 10% solids, solution B contains 25% solids and solution C contains 20% solids the equation can be written as

Solids 0.1 *5 +0.25 * X = 0.2 * Y…… EQ -2
Liquids 0.9 *5 +0.75*X = 0.8 * Y…….. EQ -3

Substituting value of Y from EQ -1 in EQ-2

0.5 + 0.25 X = 0.2 * (5 + X)

0.05 X = 0.5

X = 10 kg/s,

Substituting X in EQ-1, Y= 15 kg/s

Example 5.2

A solution which is 80% oil, 15% usable by-products and 5% impurities, enters a refinery. One output is 92% oil and 6% usable by-products. The other output is 60% oil and flows at the rate of 1000 lit/hr (assume no accumulation, percents by volume)

– What is the flow rate of input?
– What is the percent composition of the 1000 lit/hr output?
– What percent of the original impurities are in the 1000 lit/hr output?

Solution

Basis:

Input Stream A = X lit/hr
Output Stream B = Y lit/hr
Output Stream C = 1000 lit/hr

Material balance equations

1) Total: X = Y + 1000……..…….…..EQ-1
2) Oil: 0.8 * X = 0.92 * Y + 0.6 * 1000….……...EQ-2
3) UBP: 0.15 * X = 0.06 * Y + v * 1000…….….EQ-3
4) IMP: 0.05 * X = 0.02 * Y + w *1000..…….EQ-4
5) OUTPUT impurities & UBP: v + w = 0.4 ….…….EQ-5

Solving Equations 1 and 2; substituting value of X in EQ-2

0.8 (Y + 1000) = 0.92 * Y + 600
0.8 Y + 800 =0.92 Y + 600, Y = 1666 lit/hr

Substituting Y in EQ-1

X = 1666 + 1000 = 2666 lit/hr = Flow rate of input stream
Substituting value of X and Y in EQ-3, v = 30%
Substituting value of v in EQ-5, w = 10%

Thus composition of 1000 lit/hr output stream is 60% oil, 30% usable by products and 10% impurities

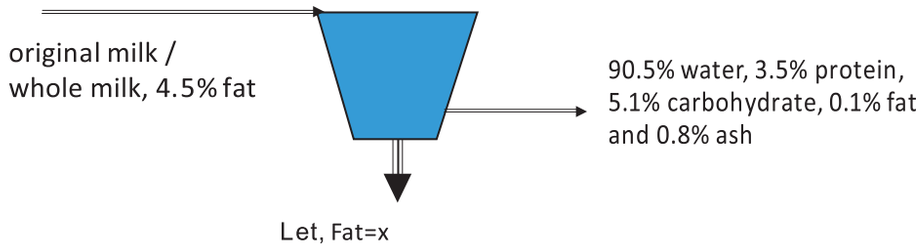
Impurities in input stream = 0.05 * 2666 = 133.3 lit/hr
Impurities in 1000 lit/hr stream (10%) =100 lit/hr

Therefore impurities in 1000 lit/hr stream as % input stream = 100/133.3 = 75%

Example 5.3: Constituent balance

Skim milk is prepared by the removal of some of the fat from whole milk. This skim milk is found to contain 90.5% water, 3.5% protein, 5.1% carbohydrate, 0.1% fat and 0.8% ash. If the original milk contained 4.5% fat, calculate its composition assuming that fat only was removed to make the skim milk and that there are no losses in processing.

Solution



Basis: 100 kg of skim milk.

This contains, therefore, 0.1 kg of fat. Let the fat which was removed from it to make skim milk be x kg.

Total original fat = (x + 0.1) kg
Total original mass = (100 + x) kg

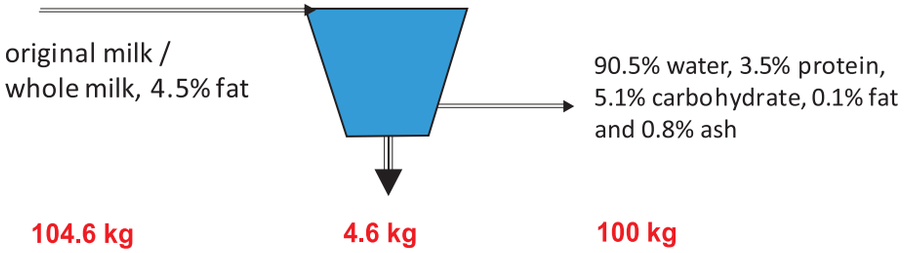
and as it is known that the original fat content was 4.5% so

$$\frac{(x + 0.1)}{(100 + x)} = 0.045$$

$$x + 0.1 = 0.045(100 + x)$$

$$x = 4.6 \text{ kg}$$

So the composition of the whole milk is then fat = 4.5%, water = 90.5/104.6 = 86.5 %, protein = 3.5/104.6 = 3.3 %, carbohydrate= 5.1/104.6 = 4.9% and ash = 0.8%



Example 5.4 Continuous Process balance

In a continuous centrifuging of milk, if 35,000 kg of whole milk containing 4% fat is to be separated in a 6 hour period into skim milk with 0.45% fat and cream with 45 % fat, what is the flow rate of the two output streams from the continuous centrifuge which accomplishes the separation?

In continuous processes, time also enters into consideration and the balances are related to unit time. Thus in considering a continuous centrifuge separating whole milk into skim milk and cream, if the material holdup in the centrifuge is constant both in mass and in composition, then the quantities of the components entering and leaving in the different streams in unit time are constant and a mass balance can be written on this basis. Such an analysis assumes that the process is in a steady state, that is flows and quantities held up in vessels do not change with time.

Solution

Basis:

Total mass input per hour = 35000/6 =5833 kg

Total mass output for skim milk = Y

Total mass output for cream = z

Material Balance Equations:

1) Mass In = Mass Out: 5833 = Y + Z (i.e. Z = 5833-Y) … EQ-1
2) Fat In = Fat Out: 0.04 * 5833 = 0.0045 * Y + 0.45 * Z … EQ-2

Substituting Z from EQ-1 to EQ-2

0.04 * 5833 = 0.0045 Y + 0.45 * (5833 –Y)

Y = 5369 kg/hr

Substituting Y in EQ -1

Z = 464 kg/hr

Example 5.5 Concentrations

A solution of common salt in water is prepared by adding 20 kg of salt to 100 kg of water, to make a liquid of density 1323 kg/m^3. Calculate the concentration of salt in this solution as a (a) weight fraction, (b) weight/volume fraction, (c) mole fraction, (d) molal concentration.

Solution

(a) Weight fraction: 20 / (100 + 20) = 0.167

% weight / weight = 16.7%

(b) Weight/volume:

A density of 1323 kg/m^3 means that 1 m^3 of solution weighs 1323 kg, but 1323 kg of salt solution contains (20 kg of salt x 1323 kg/m^3) / (100 + 20) kg = 220.5 kg salt / m^3

1 m^3 solution contains 220.5 kg salt.

Weight/volume fraction = 220.5 / 1000 = 0.2205

And so weight / volume = 22.1%

c) Moles of water = 100 / 18 = 5.56

Moles of salt = 20 / 58.5 = 0.34

Mole fraction of salt = 0.34 / (5.56 + 0.34) = 0.058

d) The molar concentration (M) is 220.5/58.5 = 3.77 moles in m^3

Note that the mole fraction can be approximated by the (moles of salt/moles of water) as the number of moles of water is dominant, that is the mole fraction is close to 0.34 / 5.56 = 0.061. As the solution becomes more dilute, this approximation improves and generally for dilute solutions the mole fraction of solute is a close approximation to the moles of solute / moles of solvent.

Example 5.6

In a textile mill, an evaporator concentrates a liquor containing solids of 6% by w/w (weight by weight) to produce an output containing 30% solids w/w. Calculate the evaporation of water per 100 kg of feed to evaporator?

Solution

Inlet solid contents = 6%
Outlet solid contents = 30%
Feed =100 kg
Solid content in kg in feed = 100 * 0.06 = 6 kg
Since mass in = mass out, the outlet solid content should be 6 kg
Output = (100/30)*6 = 20 kg
Quantity of water evaporated = [100 –20] = 80 kg

Example 5.7 Air Composition

If air consists of 77% by weight of nitrogen and 23% by weight of oxygen calculate:

(a) The mean molecular weight of air,
(b) The mole fraction of oxygen,
(c) The concentration of oxygen in mole/m^3 and kg/m^3 if the total pressure is 1.5 atmospheres and the temperature is 25 ^{0}C

Solution

(a) Taking the basis of 100 kg of air: it contains 77/28 moles of N_2 and 23/32 moles of O_2

Total number of moles = 2.75 + 0.72 = 3.47 moles.
So mean molecular weight of air = 100 / 3.47 = 28.8
Mean molecular weight of air = 28.8

b) The mole fraction of oxygen = 0.72 / (2.75 + 0.72) = 0.72 / 3.47 = 0.21
Mole fraction of oxygen = 0.21

(c) In the gas equation, where n is the number of moles present: the value of *R* is 0.08206 m^3 atm/ mole K and at a temperature of 25 ^{o}C = 25 + 273 = 298 K, and where V= 1 m^3

$$pV = nRT$$

and so, 1.5 x 1 = n x 0.08206 x 298

$$n = 0.061 \text{ mole/m}^3$$

weight of air = n x mean molecular weight
= 0.061 x 28.8 = 1.76 kg / m^3

and of this 23% is oxygen, so weight of oxygen = 0.23 x 1.76 = 0.4 kg in 1 m^3
Concentration of oxygen = 0.4kg/m^3
or 0.4 / 32 = 0.013 mole / m^3

When a gas is dissolved in a liquid, the mole fraction of the gas in the liquid can be determined by first calculating the number of moles of gas using the gas laws, treating the volume as the volume of the liquid, and then calculating the number of moles of liquid directly.

Example 5.8: Gas composition

In the carbonation of a soft drink, the total quantity of carbon dioxide required is the equivalent of 3 volumes of gas to one volume of water at 0 ^{o}C and atmospheric pressure. Calculate (a) the mass fraction and (b) the mole fraction of the CO_2 in the drink, ignoring all the components other than CO_2 and water.

Solution

Basis 1 m^3 of water = 1000 kg
Volume of carbon dioxide added = 3 m^3
From the gas equation, pV = nRT
1 x 3 = n x 0.08206 x 273
n = 0.134 mole.
Molecular weight of carbon dioxide = 44
And so weight of carbon dioxide added = 0.134 x 44 = 5.9 kg
(a) Mass fraction of carbon dioxide in drink = 5.9 / (1000 + 5.9) = 5.9 x 10^{-3}
(b) Mole fraction of carbon dioxide in drink = 0.134 / (1000/18 + 0.134) = 2.41 x 10^{-3}

Example 5.9: Dust balance

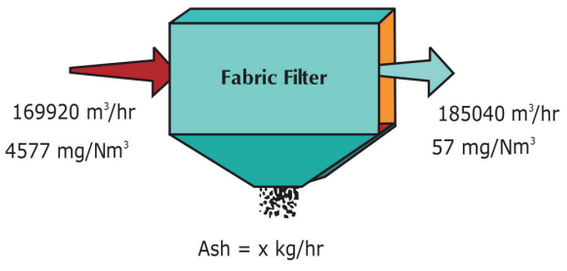
A bag filter is used to remove the dust from the inlet gas stream to meet the emission standards in cement, fertilizer and other chemical industries.

Inlet gas to a bag filter is 1,69,920 m^3/hr and the dust loading is 4577 mg/m^3.

Outlet gas from the bag filter is 1,85,040 m^3/hr and the dust loading is 57 mg/m^3.

What is the maximum quantity of ash that will have to be removed per hour from the bag filter hopper based on test results?

Solution

Dust balance, Mass $_{(in)}$ = Mass $_{(out)}$ Inlet gas dust = Outlet gas dust + Hopper Ash	

1. Calculation in/ out dust quantity
   Inlet dust qty =169920 (m^3/hr) x 4577 (mg/m^3) x 1/1000000 (kg/mg)= 777.7 kg/hr
   Outlet dust qty = 185040 (m^3/hr) x 57 (mg/m^3) x 1/1000000 (kg/mg) = 10.6 kg/hr

2. Calculate ash qty (to be removed from the hopper)
   Hopper ash = Inlet dust qty–Outlet dust qty = 777.7 kg/hr–10.6 kg/hr = 767.1 kg/hr

5.6 Energy Balance

Energy is the capacity to do work or to transfer heat. The law of conservation of energy states that energy can neither be created nor destroyed. The total energy in the materials entering the processing plant, plus the energy added in the plant must equal the total energy leaving the plant. This is a more complex concept than the conservation of mass, as energy can take various forms such as kinetic energy. Potential energy, heat energy, chemical energy, electrical energy and so on. During processing, some of these forms of energy can be converted from one to another; say for instance mechanical energy in a fluid can be converted through friction into heat energy. It is the sum total of all these forms of energy that is conserved.

For example, in the pasteurizing process for milk, the milk is pumped through a heat exchanger and is first heated and then cooled. The energy affecting the product is the heat energy in the milk. Heat energy is added to the milk by the pump and by the hot water passing through the heat exchanger. Cooling water then removes part of the heat energy and some of the heat energy is also lost to the surroundings. The heat energy leaving in the milk must equal the heat energy in the milk entering the pasteurizer plus or minus any heat added or taken away in the plant.

Heat energy leaving in milk = initial heat energy + heat energy added by pump + heat energy added in heating section - heat energy taken out in cooling section - heat energy lost to surroundings.

The law of conservation of energy can also apply to part of a process. For example, considering only the heating section of the heat exchanger in the pasteurizer, the heat lost by the hot water must be equal to the sum of the heat gained by the milk and the heat lost from the heat exchanger to its surroundings.

Conservation of Energy

In a system, if the storage does not change, the ingoing and outgoing energy must be equal (Figure 5.5 a).

If the storage changes, this must be reflected in the energy balance and the energy input to a system might not balance the energy that goes out. For instance as in Figure 5.5 b, the input is 75 units of energy but only 60 units go out. Since the first law requires that the energy be conserved, system had to gain 15 units of energy. In the Figure 5.5 c, the input is short by 15 units of energy so it can be inferred that the system must have lost 15 units.

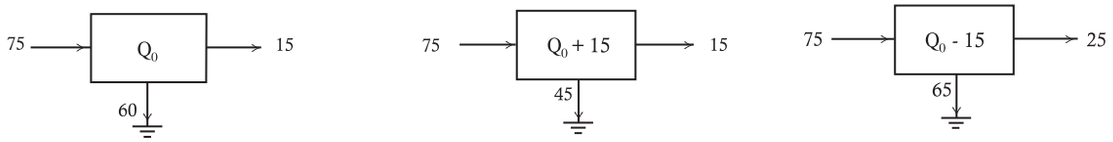


Figure 5.5 a) No Storage **b) Storage Increased** **c) Storage Decreased**

The sinks are depositories of leakage or rejected energy. It is usually low-grade heat, as in, radiation losses from boilers or heat carried away by cooling water. The outputs represent useful work.

The Figure 5.6 below illustrates power cycle schematic. In this input heat energy (Q_{in}) resulting from combustion of fuel is transferred to water in a steam generator (boiler). The fluid feed water is pumped using input energy W_{in}. The steam is used to drive the turbine and perform useful work W_{out},- and the steam is condensed in condenser giving its heat energy Q_{out} The working fluid is feed water which changes its state from water to steam and back to condensate.

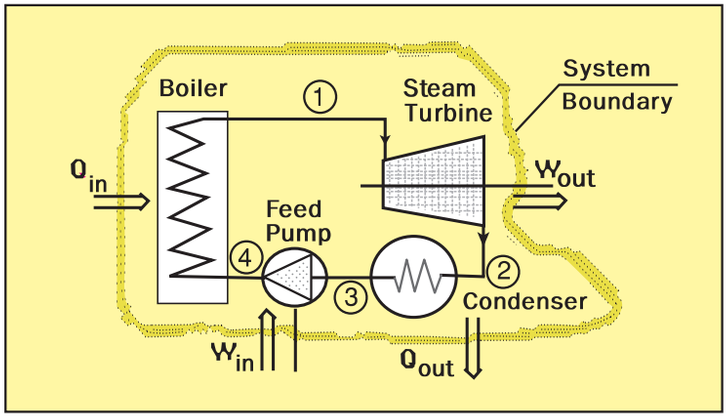


Figure 5.6 Energy Balance in Power Plant Cycle

Applying the law of conservation of energy, if a system undergoes a process by heat and work transfer, then the net heat supplied, Q plus the net work input, W. is equal to the change of intrinsic (internal) energy, DU of the working fluid, i.e.

$\Sigma Q + \Sigma W = \Delta U$

Applying this general principle to a thermodynamic cycle, when the system undergoes a complete cycle. i.e. change in internal energy, $\Delta U = 0$.

$\Sigma Q + \Sigma W = 0$

Where,
ΣQ = The algebraic sum of the heat supplied to (+) or rejected from (-) the system.
SW = The algebraic sum of the work done by surroundings on the system (+) or by the system on surroundings (-).

Applying the rule to the power plant gives:
$\Sigma Q = Q_{in} - Q_{out}$
$\Sigma W = W_{in} - W_{out}$

$$Q_{in} + W_{in} - Q_{Out} - W_{out}$$

Q_{in} = Heat supplied to the system through boiler
W_{in} = Feed-pump work
Q_{Out} = Heat rejected from the system by condenser
W_{out} = Turbine work

Efficiency

The (thermodynamic) efficiency of a process is the ratio of useful output to input and is always less than 100%. In the energy balance shown in Figure 5.7, there is no internal storage, so the sum of the inputs must equal the outgoing energy. The efficiency of the process is 22.5% and the energy lost in the system is 100 - 22.5 = 77.5%.

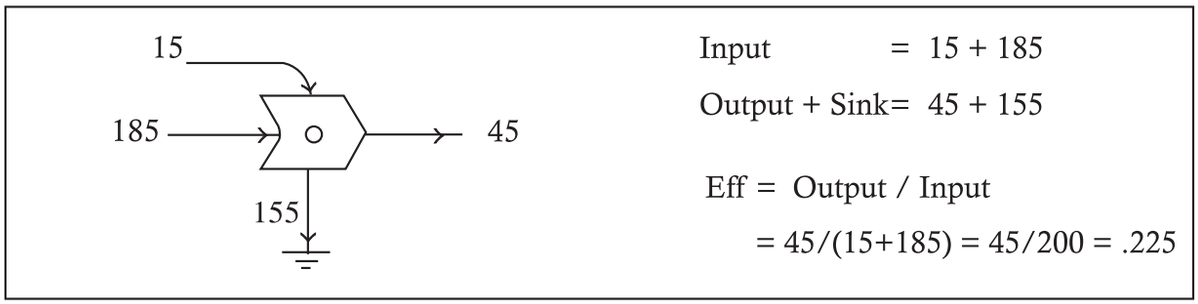


Figure 5.7 Efficiency and Losses

How can energy be lost in a system?

Energy can manifest itself in many forms such as heat, kinetic energy, chemical energy, potential energy but because of inter-conversions, it is not always easy to isolate separate constituents of energy balances. Energy is "lost" really means it changes into a form that is not counted. Most often the "uncounted' energy is work done against friction. This work changes other forms of energy into heat and wear. No energy is lost in the end, only the forms have changed.

This loss of usable energy is due to many causes

- In mechanical systems it is friction
- In electrical systems it is resistance
- In fluid systems it is turbulence, viscosity or mixing

Practically, approach to energy balance takes into account only "heat balances' ignoring internal energies. When we are unfamiliar with the relative magnitudes of the various forms of energy (oil, gas, coal, steam, chilled water or electricity) entering and exiting a particular processing situation, it is best to put them all down and convert them to equivalent "Heat Energy".

Heat Balances

The most common important energy form is heat energy and the conservation of this can be illustrated by considering operations such as heating and drying. In these, enthalpy (total heat) is conserved and as with the mass balances enthalpy balances can be written round the various items of equipment or process stages, or round the whole plant, and it is assumed that no appreciable heat is converted to other forms of energy such as work.

Enthalpy (H) is always referred to some reference level or datum, so that the quantities are relative to this datum. Working out energy balances is then just a matter of considering the various quantities of materials involved, their specific heats, and their changes in temperature or state i.e. latent heat.

5.7 Facility as an Energy System

In a production facility, the energy in form of coal, oil, gas and electricity enters the facility and is converted to more convenient forms of energy such as steam, compressed air, chilled water etc. The outgoing energy is usually in the form of heat and motion.

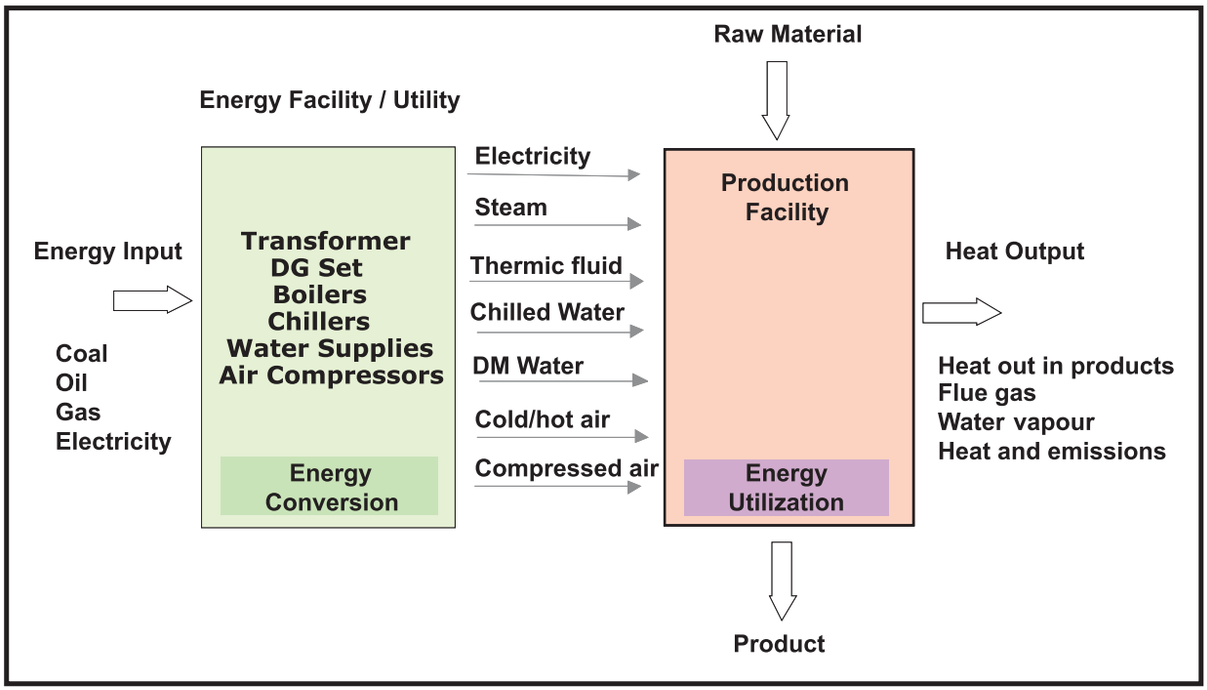


Figure 5.8 Plant Energy Systems

The energy usage in the overall plant can be split up into various forms such as (Figure 5.8):

- Electrical energy, which is usually purchased as HT and converted into LT supply for end use.
- Some plants generate their own electricity using DG sets or captive power plants.
- Fuels such as furnace oil, coal are purchased and then converted into steam or electricity.
- Boiler generates steam for heating and drying demand
- Cooling tower and cooling water supply system for cooling demand
- Air compressors and compressed air supply system for compressed air needs

All energy/utility system can be classified into three areas like generation, distribution and utilisation for the system approach and energy analysis.

Example 5.10: Furnace

A furnace shell has to be cooled from 90°C to 55°C. The mass of the furnace shell is 2 tonnes; the specific heat of furnace shell is 0.2 kcal/kg °C. Water is available at 28°C. The maximum allowed increase in water temperature is 5°C. Calculate the quantity of water required to cool the furnace. Neglect heat loss.

Solution

Energy Stream #1

Mass of furnace shell (m) = 2000 kg
Specific heat (Cp) = 0.2 kcal/kg °C
Initial furnace temperature (T_1) = 90°C

Desired furnace shell temperature (T_2) = 55°C
Total heat that has to be removed from the furnace = m x Cp x (T_1 - T_2) = 2000 x 0.2 x (90- 55)

Energy Stream #2

Quantity of water required =X kg
Specific heat of water = 1 kcal/kg °C
Inlet cooling water temperature (T_3) = 28°C
Maximum cooling water outlet temperature (T_4) = 33°C
Heat removed by water X x 1 x (33 — 28) = 5X kcal

For energy balance:
Energy Stream #1 = Energy Stream #2
or Quantity of water required (X) = 14000/5 = 2800 kg

Example 5.11: Dryer heat balance

A textile dryer is found to consume 4 m^3/hr of natural gas with a calorific value of 800 kJ /mole. If the throughput of the dryer is 60 kg of wet cloth per hour, drying it from 55% moisture to 10% moisture, estimate the overall thermal efficiency of the dryer taking into account the latent heat of evaporation only.

Solution

1) Initial moisture in wet cloth =60 x 0.55 = 33 kg moisture
2) Bone dry cloth = 60 x (1-0.55) =27 kg bone dry cloth
3) Final product moisture content 10% = 27/9 = 3 kg
4) So moisture removed /hr = 33 - 3 = 30 kg/hr
5) Latent heat of evaporation = 2257 kJ/kg
6) Heat used for drying cloth = 30 x 2257 = 6.8 x 10^4 kJ/hr
7) Assuming the natural gas to be at standard temperature and pressure at which 1 mole occupies 22.4 liters
8) Rate of flow of natural gas = 4 m^3/hr = (4 x 1000)/22.4 = 179 moles/hr
9) Heat available from combustion 179 x 800 =14.3 x 10^4 kJ/hr
10) Approximate thermal efficiency of dryer = heat needed I heat used = 6.8 x 10^4 /14.3 x 10^4 = 48%

To evaluate this efficiency more completely it would be necessary to take into account the sensible heat of the dry cloth and the moisture, and the changes in temperature and humidity of the combustion air, which would be combined with the natural gas. However, as the latent heat of evaporation is the dominant term, the above calculation gives a quick estimate and shows how a simple energy balance can give useful information.

Example 5.12- Evaporation Rate

Production rate from a paper machine is 340 tonnes per day (TPD). Inlet and outlet dryness to paper machine is 40% and 95% respectively. Evaporated moisture temperature is 80 °C. To evaporate moisture, the steam is supplied at 35 kg/cm^2. Latent heat of steam at 35 kg/cm^2 is 5l3 kcal/kg. Assume

24 hours/day operation a) Estimate the quantity of moisture to be evaporated b) Input steam quantity required for evaporation (per hour). Consider enthalpy of evaporated moisture as 632 kCa1/kg.

Solution

Production rate from a paper machine: 340 TPD or 14.16 TPH (tonnes per hour)
Inlet dryness to paper machine: 40%
Outlet dryness from paper machine: 95%

Estimation of moisture to be evaporated
Paper weight in final product: 14.16 x 0.95 = 13.45 TPH
Weight of moisture before dryer: [(100-40)/ 40] x 13.45 = 20.175 TPH
Weight of moisture after dryer: 14.16 x 0.05 = 0.707 TPH
Evaporated moisture quantity: 20.175 - 0.707 =19.468 TPH

Input steam quantity required for evaporation
Evaporated moisture temperature: 80 °C
Enthalpy of evaporated moisture: 632 kcal/kg
Heat available in moisture (sensible & latent): 632 x 19468 = 12303776 kcal/h

For evaporation minimum equivalent heat available should be supplied from steam
Latent Heat available in supply steam at 3.5 kg/cm^2 = 513 kcal/kg
Quantity of steam required: 12303776/513= 23984 kg or 23.98 MT/hour

5.8 Energy Analysis and the Sankey Diagram

The basic data needed for an energy analysis is an energy balance of each process section. The objective is to define in detail the energy input, energy utilized, and the energy dissipated or wasted. This is best represented by a Sankey diagram. The Sankey diagram is very useful tool to represent an entire input and output energy flow in any energy equipment or system such as boiler generation, fired heaters, furnaces after carrying out energy balance calculation. Usually the flows are represented by arrows. The width of the arrows is proportional to the size of the actual flow. Better than numbers, tables or descriptions, this diagram represents visually various outputs (benefits) and losses so that energy managers can focus on finding improvements in a prioritized manner.

Sankey Diagram

The Figure 5.9 shows a Sankey diagram for an internal combustion engine. From the Figure, it is clear that exhaust flue gas losses are a key area for priority attention. Since the engines operate at high temperatures, the exhaust gases leave at high temperatures resulting in poor system efficiency. Hence a

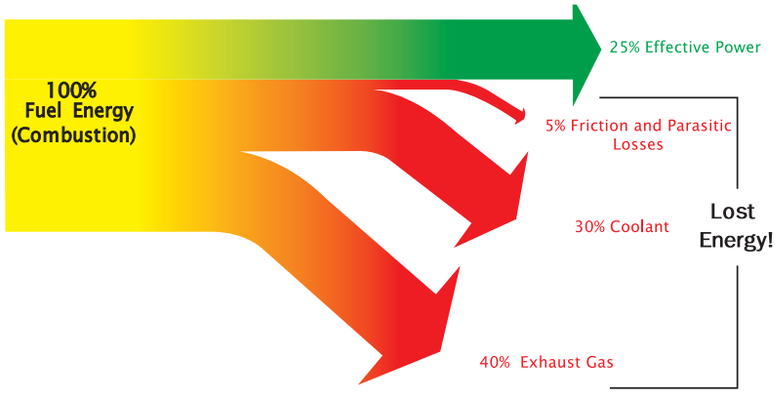


Figure 5.9 Sankey Diagram for an Internal Combustion Engine

heat recovery device such as a waste heat boiler has to be necessarily part of the system. The lower the exhaust temperature, higher is the system efficiency. Further improvements can be thought of by utilising the heat in the cooling water circuit for a vapour absorption refrigeration system.

Solved Example:

An evaporator is to be fed with 10,000 kg/hr of a solution having 1 % solids. The feed is at 38°C. It is to be concentrated to 2% solids. Steam is entering at a total enthalpy of 640 kcal/kg and the condensate leaves at 100°C. Enthalpies of feed are 38.1 kcal/kg, product solution is 100.8 kcal/kg and that of the vapour is 640 kcal/kg. Find the mass of vapour formed per hour and the mass of steam used per hour.

Ans:

Mass of vapour

Feed = 10,000 kg/hr @ 1 % solids

Solids	=	10,000 x 1/100
	=	100 kg/hr
$Mass_{out}$ x 2/100	=	100
$Mass_{out}$ = 10,000/2	=	5000 kg/hr
Vapour formed	=	10,000 – 5000
	=	5000 kg/hr
Thick liquor	=	5000 kg/hr

Steam consumption:

Enthalpy of feed = 10,000 x 38.1 = 38.1 x 10^4 kcal

Enthalpy of the thick liquor = 100.8 x 5000 = 5,04,000 kcal

Enthalpy of the vapour = 640 x 5000 = 32,00,000 kcal

Heat Balance:

Heat input by steam + Heat in feed = Heat out in vapour + Heat out in thick liquor

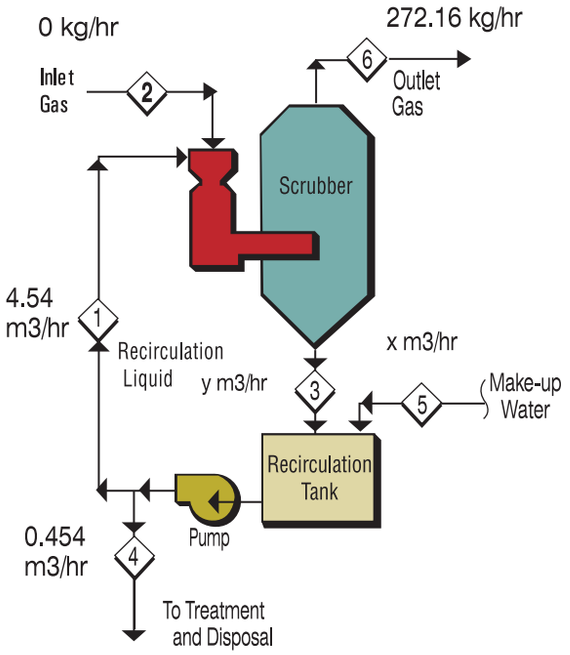
[M x (640-100) + 38.1 x 10,000] = (32,00,000 + 5,04,000)

M x 540 = 33,23,000

Mass of steam required = 33,23,000/540

= **6153.7 kg/hr**

QUESTIONS	
Objective Type Questions	
1.	The objective of material and energy balance is to assess the a) input-output b) conversion efficiency c) losses d) all the above
2.	In the material balance of a process or unit operation process, which component will not be considered on the input side? a) chemicals b) water/air c) recycle d) by product
3.	In material balance of a process, recycle product is always considered as a) input to process b) output to process c) both (a) and (b) d) none of them
4.	In a chemical process two reactants A (200 kg) and B (200kg) are used as reactants. If conversion is 50%, A and B react in equal proportion then calculate the weight of the product formed is. a) 150 kg b) 200 kg c) 250 kg d) 400 kg
5.	In a heat treatment furnace the material is heated up to 800 °C from ambient temperature of 30 ° C. Considering the specific heat of material as 0.13 kcal / kg °C what is the energy content in one kg of material after heating? a)150 kcal b) 250 kcal c) 350 kcal 4) 100 kcal
6.	In a utility steam boiler, heat loss due to radiation normally is in the range of a) 10% b) 14% c) 1% d) 8%
7.	Energy supplied by electricity, Q in kcal is equal to _____. a) kWh x 8.6 b) kWh x 86 c) kWh x 860 d) none
8.	Sankey diagram is a useful tool to represent ____. a) financial strength of the company b) management philosophy c) input and output energy flow d) human resource strength of the company
9.	Which of the following formula is useful to determine the heat duty in conducting heat balance? a) $Q = M\ Cp\ \Delta\ T$ b) $Q = AV$ c) $PV = n\ RT$ d) none of the above
10.	A 230V , 100 W rated incandescent bulb is operated at a constant voltage of 250V. The approximate power consumption of bulb is a) 100 W b) 118 W c) 85 W d) none of the above
Short Type Questions	
S-1	During an air pollution monitoring study, the inlet gas stream to a bag filter was 200,000 m^3 per hour. The outlet gas stream from the bag filter was a little bit higher at 210,000 m^3 per hour. Dust load at the inlet was 6 gram/ $m^3$and at the outlet 0.1 gram/ m^3 . How much dust in kg/hour was collected in the bag filter bin?
S-2	Explain sankey diagram with an example

S-3	A sample of coal from the mine is found to contain 67.2% carbon and 22.3% ash. The refuse obtained at the end of combustion is analyzed to contain 7.1% carbon and the rest is ash. Compute the % of the original carbon unburnt in the refuse.
S-4	A boiler is fed with soft water containing 120 mg/l dissolved solids. As per IS standards the maximum dissolved solids in the boiler should not exceed 3500 mg/l for boilers, operating up to 2 MPa. In order to maintain the specified level, a continuous blow down system is adopted. Find the percentage of feed water which will be blown down.
S-5	A shell and tube heat exchanger is cooled with stream of demineralized water. Evaluate the total heat rejected to cooling water (kcal/hr), if the water flow rate is 200 m^3/hr and the temperature rise is 7°C.
Long Type Questions	
L-1	A scrubber is used to remove the fine material or dust from the inlet gas stream with a spray of liquid (typically water) so that outlet gas stream meets the required process or emission standards. How much water must be continually added to wet scrubber shown in Figure in order to keep the unit running? Each of the streams is identified by a number located in a diamond symbol. Stream 1 is the recirculation liquid flow stream back to the scrubber and it is 4.54 m^3/hr. The liquid being withdrawn for treatment and disposal (stream 4) is 0.454 kg m^3/hr. Assume that inlet gas stream (number 2) is completely dry and the outlet stream (number 6) has 272.16 kg/hr of moisture evaporated in the scrubber. The water being added to the scrubber is stream number 5. 
L-2	An autoclave contains 1000 cans of pea soup. It is heated to an overall temperature of 100 °C. If the cans are to be cooled to 40 °C before leaving the autoclave, how much cooling water is required if it enters at 15 °C and leaves at 35 °C? The specific heats of the pea soup and the can metal are respectively 4.1 kJ/ kg °C and 0.50 kJ/ kg °C. The weight of each can is 60g and it contains 0.45 kg of pea soup. Assume that the heat content of the autoclave walls above 40 °C is 1.6 x 10^4 kJ and that there is no heat loss through the walls.

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2. Energy Management Handbook, John Wiley and Sons - Wayne C. Turner
3. Unit Operations in Food Processing, R.L. Earle, NZIFST

Chapter 6

Energy Action Planning

Learning Objectives

In this chapter you will learn about

- Key elements for successful energy management
- Understanding force field analysis
- Organizing for effective energy management
- Roles and responsibilities of top management and energy manager
- Importance of motivating and training employees
- Requirements for energy action planning
- Energy information systems
- Use of management techniques and systems

6. ENERGY ACTION PLANNING

Energy policy, Key elements, Formulation, Ratification, Organizing – location of energy management, Top management support, Managerial function, Roles and responsibilities of energy manager, Accountability, Force field analysis, Marketing and communicating-training and planning, Motivation information system-designing, Barriers, Strategies, Management tools (5S, TPM, TQM, Kaizen, small group activities, ISO 50001)

6.1 Introduction

Most organisations will have an energy audit conducted by an independent audit firm and then implement few of the findings to reduce the energy consumption. Subsequently they may not make any further effort for several years till the next energy audit. In contrast, organisations which have established an energy action plan make continual effort to monitor and improve the energy efficiency and energy productivity. These organisations have integrated energy management with existing management techniques and have permanent focus on energy consumption reduction and energy cost control

Planning is one of the most important components of the energy management program, and for many technical people it is the least desirable. It has two major functions in the program. First, a good plan can be a shield from disruptions. Second, by scheduling events throughout the year, continuous emphasis can be applied to the energy management program, and this will play a major role in keeping the program active. Such events can be in the form of training programs, audits, planning sessions, demonstrations, research projects, lectures, etc.

Developing objectives, strategies, programs and action items constitutes strategic planning for the energy management program. It provides the basis for resources such as funding and personnel for implementation. It incorporates energy action planning into overall strategic planning by the organization, and hence it legitimizes the program at top management level.

The various steps in energy action planning (Figure 6.1) are:

- ✓ Top Management Commitment and Support
- ✓ Assessing Energy Profile and Establishing Baseline
- ✓ Energy Policy and Planning
- ✓ Implementation
- ✓ Evaluating Energy Performance
- ✓ Recognizing Achievements

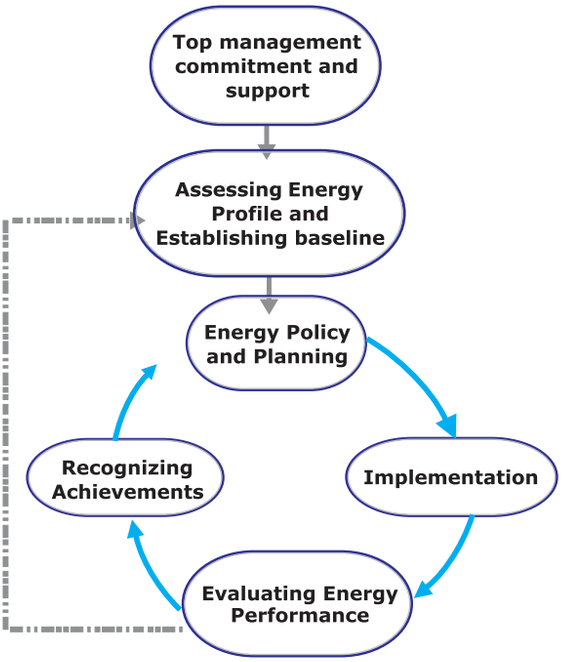

Figure 6.1 Energy Action Planning Steps

6.2 Top Management Commitment and Support

Top Management Support

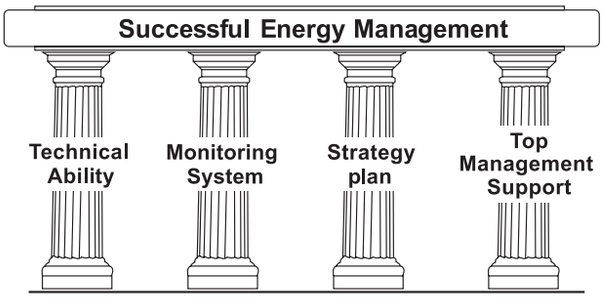

Figure 6.2 Successful Energy Management

The four vital requirements for a successful energy management programme is shown in Figure 6.2. Any successful energy programme within an organization needs the total support of top management. If the top management accepts the view that energy efficiency is good business, implementation of the energy management program will become easier. It can be integrated with existing management techniques that are already in place to deal with man power, raw materials etc. The other important requirements are a well-charted strategy plan, an effective monitoring system and adequate technical ability for analyzing and implementing energy saving options.

In companies, which do not already possess an energy efficient ethics, good communication downwards from senior management will be vital. Having decided on a policy of energy conservation, senior executives should initially at least demonstrate their commitment to the new policy through their actions. They should actively participate in the organization and planning of the energy management campaign and should be seen to demonstrate strong personal commitment to the goal.

Finally, an important part of top management commitment is to establish an organization structure for implementing the energy management programme. This is commonly at two levels: energy committee and the energy manager. Evidence of top management commitment will be seen in the level of support given to the committee and the energy manager, especially through authorization of resources and participation in meetings.

Motivation of Employees

One of the most successful means of motivating employees is through "awareness". Employees can be stimulated to support an energy management program if they are informed of (1) the amount of energy they are using (2) the costs involved (3) the critical part that energy plays in the continued viability of their job (4) the many ways in which they can save energy in their operation (5) the relationship between production rate and energy consumption and (6) the seriousness of the energy problem and its potential impact upon country economy in the future.

Another effective way to motivate employees is through recognition. The employees are committed,

3 key factors of motivation

1. Motivation is already within people. The task of supervisor or manager is not to provide motivation, but to know how to bring it out.
2. The amount of energy and enthusiasm employees are willing to invest in their work varies with the individuals. Not all are over-achievers., but not all are lazy either.
3. The amount of personnel satisfaction to be derived determines the amount of energy an employee will invest in the job

if they are involved personally in setting realistic, but challenging targets. Energy conservation goals must be decided by the operating department and not be dictated by senior management. Healthy competition between departments and plants must be encouraged to motivate them to set the goals higher and to work harder to achieve them. A documented program by each department and every plant on how they plan to attain their goals should accompany these goals. The program will contain activities and assigned responsibilities that will lead to reaching the goals.

If possible, energy management activities can be made a part of each supervisor's performance or job standards. Another potential area for motivating employees to generate creative ideas in saving energy is rewards, either as cash awards or certificates. The other aspect concerns purchasing energy-efficient equipment. The purchase department should be aware of and use the concept of "life-cycle" costing. In deciding which equipment to buy, the purchasing manager should consider the annual savings that can result from purchasing more efficient equipment versus the higher cost of the equipment.

Appointment of Energy Manager

To develop and maintain vitality for the energy management program, a company must designate a person who has responsibility for coordinating the program. If no one has energy management as a specific part of his or her job assignment, management is likely to find that the energy management efforts are given a lower priority than other job responsibilities.

The energy manager should be strong, dynamic, goal oriented, and a good manager. Such a person should be supported by management with resources including staff. The energy manager should report as high as possible in the organization without losing line orientation. Energy Manager location can vary from one organization to another depending upon existing management structure. The location of Energy Management function in a typical textile mill is shown in Figure 6.3.

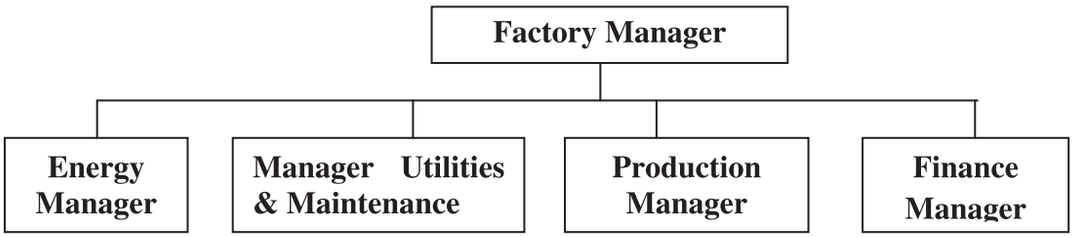

Figure 6.3 Energy Cell in a Typical Textile Mill

Responsibilities and Duties of Energy Manager

Responsibilities

1. Prepare an annual activity plan and present to management concerning financially attractive investments to reduce energy costs.
2. Establish an energy conservation cell within the firm and agree with management about the mandate and task of the cell.
3. Initiate activities to improve monitoring and process control to reduce energy costs.
4. Analyze equipment performance with respect to energy efficiency.
5. Ensure proper functioning and calibration of instrumentation required to assess level of energy consumption directly or indirectly.

6. Prepare information material and conduct internal workshops about the topic for other staff.
7. Improve disseminating of energy consumption data down to shop level or profit center of a firm.
8. Establish a methodology to accurately calculate the specific energy consumption of various products/services or activity of the firm.
9. Develop and manage training programme for energy efficiency at operating levels.
10. Co-ordinate nomination of management personnel to external programs.
11. Create knowledge bank on sectorial, national and international development on energy efficiency technology and management system and information denomination.
12. Develop integrated system of energy efficiency and environmental up gradation.
13. Wide internal and external networking
14. Co-ordinate implementation of energy audit/efficiency improvement projects through external agencies.
15. Establish and / or participate in information exchange with other energy managers of the same sector through association.

Duties of Energy Manager

1. Report to BEE and State level Designated Agency once a year. The information with regard to energy consumed and action taken in the recommendation of the accredited energy auditor, as per BEE – Format.
2. Establish an improved data recording, collection and analysis system to keep track of energy consumption.
3. Provide support to Accredited Energy Audit Firm retained by the company for the conduct of energy audit.
4. Provide information to BEE as demanded in the Act, and with respect to the tasks given by the mandate, and the job description.
5. Prepare a scheme for efficient use of energy and its conservation and implement such scheme keeping in view the economic stability of the investment in such firm and manner as may be provided in the regulations of the Energy Conservation Act.

Marketing Energy Management Program

One of the most important role of energy manager is marketing or selling energy management program to top management. The best way to convince management is with facts and statistics using graphs.

The data can also supported with quotes from other companies for showing saving goals are realistic. Other company experiences are widely published in the literature; results can also be obtained through direct contacts with the energy manager in each company.

Energy Committee

Since, not all the talent necessary for a successful energy management program resides in one person or discipline, several engineering disciplines may be necessary to accomplish a full-scale study of the plant involving thermal and electrical system. For this reason, most successful energy management programs have a committee. The committee is usually composed of several persons with strong technical

background in their discipline. Chemical, industrial, electrical, civil, and mechanical engineers as well as others may all be represented in this committee. Their responsibility is to provide technical assistance for the energy manager and plant-level people. For example, the committee can keep up with developing technology and research into potential applications company-wide. The results can then be filtered down.

While the energy manager /energy management coordinator may be a full-time position, the committee is likely to operate part-time, being called upon as necessary. In a multi-plant or multidivisional organization, the committee may also be full time.

The frequency of committee meetings depend on the importance of energy costs in the overall cost structure of the company and what projects are in progress at that time. Normally a monthly meeting is usual, so that monthly production and energy consumptions may be reviewed regularly by the committee. This review would include a comparison of actual performance against previously set targets and budget figures, as well as against previous months. Other items for the agenda should be a review of the status of energy conservation projects under implementation or planned.

Having a committee can encourage communications and the sharing of ideas among various departments (and even other plants) throughout the company. It can serve to obtain agreements on energy conservation projects, which affect more than one department. It can provide a stronger voice to the top management than a single energy manager normally could.

6.3 Assessing Energy Profile and Establishing Baseline

Before trying to make out any future programs or action plans, it is essential for the company or factory management to understand the current and past energy situation or the organisation.

Energy Data Collection and Management

The first step is to find out how, when, where energy is being used. This information is necessary for establishing baselines and managing energy use.

a) Collect data

The data must be complete and accurate as it would be used for analysis and setting goals. The current data for energy consumption can be obtained by measurements, calculations or estimation.

The level and scope of data collection will vary from organisation to organisation. The sources of data are normally utility bills and sub-meters on individual processes, if available.

All sources of energy (electricity, steam, oil, natural gas, waste fuels), purchased or generated on-site must be accounted in physical units (kWh, kg of steam, etc.) and on cost basis.

Atleast two years of data must be assembled and summarized monthly. More recent data must be used if available.

b) Track data

Along with data, non-energy related data for all facilities and operations such as building size, production, operating hours etc. have to be collected. This will also help in establishing Energy Performance Indicators (EPI).

c) Normalize data

The energy use of facilities varies widely for reasons other than energy efficiency of equipment and operations. These factors may include season, occupancy, raw material quality or other operating characteristics. Normalization is the process of removing the impact of other factors on energy use so that energy performance of facilities and operations can be compared.

For industrial facilities, normalization factors include inputs, product type, output, production process etc.

For commercial buildings, common normalization factors include, climate zone, building area, energy choice, cost of energy, occupancy levels, hours of operation etc.

d) Establish Baseline

The purpose of baseline is to determine reference point from which to measure progress.

- Establish energy baseline considering a minimum of 12 months of data. A baseline considering average for past two to three years is more desirable.
- Identify Energy Performance Indicators (e.g. kcal/ton, kcal/kWh, total energy cost/ton)
- Publish and share the baseline with managers and other key stakeholders in the organisation.

e) Analyse energy use pattern and trends

Analysing data to determine energy use and trends can help to better understand factors that affect energy performance and identify steps for reducing energy consumption.

- Based on energy use data, identify facilities, equipment, systems, and processes of the organisation that significantly affect energy use. The significant energy consumption is that which accounts for a high proportion of the total energy consumption of the organisation
- Determine the current performance of facilities, equipment, systems, and processes related to the identified significant energy uses.

The data can be analysed through quantitative or qualitative reviews:

Quantitative Review

- Identify energy consumption peaks and valleys and determine how they relate to key operations or events
- Compare the performance data of similar facilities

Qualitative Review

- Conduct interviews and seek informed opinions from colleagues, lessons learned, system-specific information through in-house audits and surveys
- Review policies and operating procedures to determine impact of energy use

The future trend of energy supply-demand balance is estimated based on analysis and projection of historical data. The data on future trend would also be a basis of the program of good Energy Management

The energy profile shall be updated at defined intervals and in response to major changes in facilities, equipment, systems, or processes.

Conducting Energy Audit

Determining the organization's baseline energy use and energy performance is only a starting point. Subsequently, the operating performance of facility systems and equipment is more comprehensively evaluated and accurate baseline is determined by conducting a detailed energy audit. Energy audit should cover all energy using systems, processes and equipment. Energy audit is conducted by energy auditor to evaluate the actual performance against desired performance or best available technology. The differences indicate the potential for actual savings.

The energy audit report is prepared on completion of energy audit containing detailed summary of actual steps that can be taken to reduce energy use. The report should contain recommended actions ranging from simple adjustments in operation to complete equipment replacement. Estimate of investments for completing actions should also be included.

6.4 Energy Policy and Planning

Good planning is a basis and starting point of effective energy action planning. The basis for policy and planning is based on the premise - Strategic goals are only achieved if driven by day-to-day actions. The various components of planning are:

- Developing an energy policy.
- Setting objectives and targets.
- Preparing detailed action plans.
- Allocating management resources.
- Utilizing various management techniques (5S, TPM, TQM, Kaizen, ISO 50001) for effective implementation.

Develop an Energy Policy

Energy policy provides the foundation for setting performance goals and integrating energy management into an organisation's culture and operations.

It is a well-established fact that a formal written energy policy acts both as:

- A public expression of an organisation's commitment to energy management
- A working document to guide energy management practices and provides continuity.

It is in the company's best interest that support for energy management is expressed in a formal written declaration of commitment accompanied by a set of stated objectives, an action plan for achieving them, and clear specifications of responsibilities.

Actual drafting of energy policy will depend on an organisation's corporate culture and management style. The policy will get wider acceptance if all the concerned parties have been given the opportunity to contribute to its formulation. All departmental representatives should be invited to make submissions when the policy is first formulated and again when it is reviewed. After the policy is drafted, it should be formally adopted and ratified by the head of the organisation.

The format of the energy policy statement is various, but it usually includes the goal or objective of the company and the more concrete targets in the field of Energy Management (or Energy Conservation). It often shows the major measures and timetables. The statement shall match the company's mission statement or overall management strategy plan.

Generic Energy policy (Short version)

The company is committed to purchasing and using energy in most efficient, cost-effective and environmentally responsible manner possible. Towards this end, the company will:

Improve energy efficiency by implementing effective energy management programmes that support all operations and customer satisfaction while maintaining a safe and comfortable working environment.

Objectives

- Benchmark all premises by March 2011.
- Reduce energy use per output by 15 per cent, relative to the 2009 base year, by 2012.
- Implement a programme of staff awareness and education on energy issues.
- Purchase 10 per cent of our energy use from renewable sources by 2012.

This policy applies to our entire site.

Approved: Chairman
Date: 20 June 2010

Establish Goals

Once the potentials for improvement have been estimated, goals can be established at the appropriate organisational levels. Setting goals ensures that organisation has defined success criteria so that progress towards energy efficiency can be measured. The goals should be formally approved by senior management.

The goals should be measurable with time frame set for achievement. Goals can be set based on energy audit findings or what is technically or economically feasible or using benchmarking information. The goals can be long-term or medium term.

Few examples of goals are:

– Reducing specific energy consumption of clinker from 100 kWh/ton to 90 kWh/ton of furnace oil by 2012
– 10% reduction of coal consumption by end of 2011

– Increase staff awareness on energy issues
– Use of renewable energy etc.

A good rule for setting goals is start with small goals

First year goals of 3 to 6% of energy consumption reduction or specific energy consumption reduction are quite adequate for most companies.

Another way is to develop a goal over several years; for example, set up a goal of 20% energy savings over 3 years. The yearly goals are usually better, however, as the reward can be seen sooner, success celebrated more often, and adjustments and corrections to goals can be made more frequently, especially if plant production changes.

Set targets

Targets are normally set at departmental levels to achieve the organisational goals.

The targets can relate to the whole organisation, to one site, to a production process or even to particular equipment. A company may set a range of targets for different departments, taking into account the scope for improvement. Ideally, targets should be attainable, but challenging.

Targets should be **SMART** i.e.:
(a) **S**pecific and **M**easureable
(b) **A**mbitious so as to commit the organisation to continual improvement
(c) **R**ealistic, so that they can be achieved within specified **T**ime limits

As a minimum, targets should be established for each of the significant energy issues or aspects identified during the initial phase. Some targets may apply to equipment or facilities (e.g. a specific production line) while others may address the energy consumption of departments (e.g. transport and logistics department), training or energy awareness, additional measurement and monitoring.

Energy reduction targets could be expressed through energy performance indicators such as energy consumption per item, per kg, per m^2 or % or equivalent.

Examples of targets are:

– Reducing raw mill power consumption by 20% by modifying the raw mill fan by July 2010
– Achieve 10% reduction in power consumption in air compressors by modifying the piping system by April 2011.

Use of Benchmarking for setting goals and targets

“Benchmarking” is a general term in the field of business administration or corporate management, meaning “gathering information on performance of others and compare” or “learn from others”. By benchmarking themselves against others who are best in the field, companies can learn more efficient ways of operating.

If companies could get good Benchmarking figures, they might be utilized as reference for goal setting or targeting. Though Benchmarking is an effective tool for performance comparison and improvement,

it should be used carefully, because it requires detailed data and information on not only energy type and consumption but also on manufacturing or production processes. The latter includes information on raw materials, products (types and grades), processes and other related conditions. Inaccurate comparison not standing on the same basis would give the misleading results. Finally, if companies want to use benchmarking externally to establish targets, they should get very detailed information from other companies and there are issues of confidentiality in sharing information. In such situations, company can use their own historical best as the basis for setting targets. This is called internal benchmarking.

Create Action Plans

Action Plans are basically Energy Management Programs established to ensure that organisation achieves its goals and targets. The energy management programs should detail how the organisation plans to improve energy efficiency and should contain a description of the tasks and resources required for their implementation. To avoid duplication of resources, action plans should be incorporated into normal business operations.

Steps in creating action plans

a) Evaluate energy audit reports and identify gaps between current and desired performance (goals/targets)
b) Identify and list activities need to reach desired performance from current performance for each action plan
c) List resources and time required for reaching the goals/targets
d) Designate overall responsibility for each action plan
e) Facilitate budget negotiations and confirm budget availability for each action plan

Action plans should be communicated to relevant departments as it may involve roles and contribution from various departments such as utility management, operations management, human resources, purchase, engineering, environment, health and safety etc.

Force Field Analysis

Before creating the action plan, it can be a useful exercise to clarify the goal to be achieved, and to assess what barriers must be overcome and what influences exist in the organisation that works towards the achievement of the goal. These barriers and influences can be thought of as negative and positive forces respectively. Force field analysis is a smile tool that can be used to gain additional insight about the change process to be pursued. The steps involved in force field analysis are:

State the organisational goal and indicate the direction (say, left to right) that signifies moving towards the goal: for example, the goal might be “improve energy efficiency in the assembly plant” or “reduce energy consumption in the facility for current occupancy levels”

Identify barriers that tend to work against the achievement of the goal: these may be internal to the organisation (for example, a lack of expertise related to energy management) or external (for example, energy rate structures or government regulation).

Identify positive influences or forces that tend to work towards achievement of the goal; these may also be internal or external.

Estimate the relative strength of the negative and positive forces (for simplicity, we may want to identify them as low, medium and high strength)

Prioritize those forces that can be strengthened or weakened through the action plan with the greatest effect on achieving the goal (Tips: It is usually more effective to attempt to minimize negative forces than to try to strengthen forces that are already positive). A typical force field analysis chart is shown in Figure 6.4.

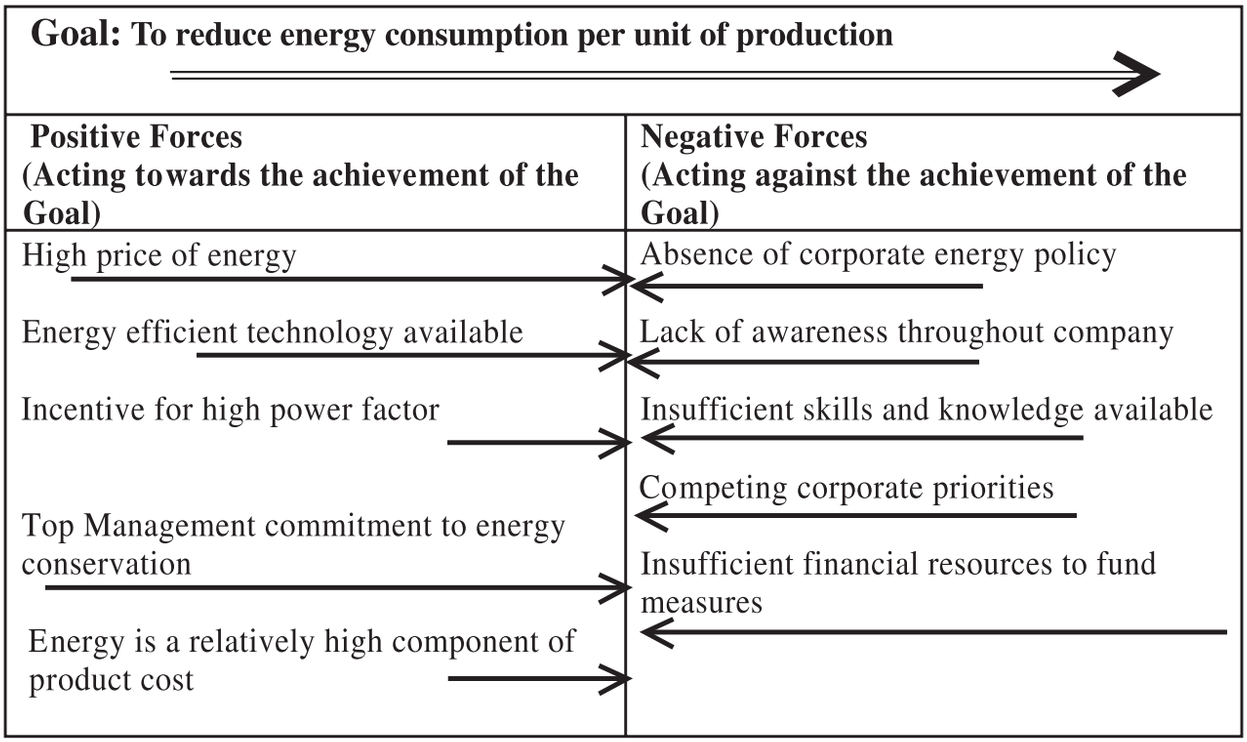

Figure 6.4 Force Field Analysis

6.5 Implementation

The energy manager / committee established in the planning step shall ensure smooth implementation of the program. People can make or break an energy program. Gaining the support and cooperation of key people at different levels within an organisation is an important factor in successful implementation of the action plans.

Reaching the goals depends on the awareness, commitment and capability of the personnel who will implement the activities listed in the action plans. For effective implementation, the following need to be considered:

Communication

Create communication plan: Develop targeted information for key employees about the energy management program i.e. organisation energy performance, current energy use and trends, financial benefits of improved performance.

Communication should raise general awareness, commitment and participation at all levels within the organisation so as to build support at all levels of the organisation for energy management initiatives and goals. Employees are encouraged to make suggestions for improvement.

Raising General Awareness: Most employees will not be aware of how their daily actions and activities at work affect energy use and impact the environment. Increasing awareness can be an effective way to gain greater support for energy management initiatives.

For new employees, basic information on energy use should be provided during orientation program.

Improving Facility Energy Awareness: Even individuals working in or managing a facility may have little understanding of the facility energy performance. For awareness programs, the following information may be imparted:

- Energy use statistics (overall energy costs, operating cost of equipment etc.)
- Energy use of equipment (energy performance of equipment or processes)

The different methods of communication include informal dialogue, regular work group meetings, posters, newsletters, bulletin boards and intranet sites.

Training

Training is the key to sustain energy conservation. It is the management responsibility to ensure that technical and operating personnel are trained to operate the equipment safely and efficiently. Effective training is not accomplished in a single session that once completed, may be quickly forgotten. Training must be continuous to help not only to inform but also to change attitudes.

Top management must give proper support to its Energy Committee, and to the Energy Manager in the form of training. Training allows the staff to explore new ideas, interact with experts and with other trainee participants, and feel more comfortable with the role they must fulfil. In turn, trained technical and management staff should be encouraged to provide in-house training to operators and lower level technical staff.

Staff training is the primary tool by which awareness is generated and knowledge is transmitted. As part of the Energy Management program, management needs to address two major areas for employee training:

(1) To develop new skills in technologies (in-house or outside training)
(2) To adopt new attitudes towards energy wastage and reduction of waste.

The introduction of new technologies, process equipment, operating and maintenance procedures and energy documentation methods require training at many levels. There is a need to train new as well as experienced personnel in energy efficient operation of company facilities. The need for training in each should be reviewed periodically to assure that all new personnel are properly trained and skills of existing personnel are refreshed.

Use of knowledge and Information System

Computer based information system provide an excellent means of sharing information on best practices, technologies and operational manuals and guidance in the field of energy management. These systems

can vary from complex knowledge based database to simple intranet site. They are centralized for easy accessibility within an organisation.

Awareness and Motivation

Top management or energy manager should determine strategies on how to motivate their staff so that they are encouraged to give cooperation in energy savings taking into account environmental impact, depleting natural resources and increasing energy price.

Motivation of people to save energy is a challenging job of the energy manager. It is an opportunity for energy manager to be accepted by the top management if he/she is successful.

Building morale and encouragement

- Ask staff what they think or know about energy losses and how to reduce them
- Agree on objective, target and results of energy audit
- Give incentives, rewards to any responses

Good practices for building awareness and motivation

- Top management gives strong attention to energy conservation, sets up and announces energy conservation policy
- Top management support energy conservation team and activities
- Top management gives incentives, rewards or recognition to individual or team who succeed in energy conservation projects
- Follow up the projects and announce results of energy conservation to all employees
- Try to get participation from all the people concerned in every steps i.e. suggestion, making decision, implementation, follow up and evaluation
- Inform all the key staff of the organization about energy losses and convince them the benefit of energy savings. This would draw attention of the remaining staff to participate
- Working group consisting of representatives from each division would encourage and support their staff to implement energy saving measures
- At the end of every month there would be an evaluation of energy consumption and energy saved in comparison with that of the past
- Organize in house training by utilizing inside and outside qualified speakers
- Organize energy conservation week once a year with various activities e.g., seminars, exhibitions, contests etc.

6.6 Evaluating Energy Performance

Tracking and monitoring

Energy Action Plans are tracked on a periodic basis for meeting goals and targets. The actual energy use is compared with expected consumption to spot deviations. Accordingly, appropriate responses are planned.

For effective monitoring, metering and sub-metering have to be introduced. The measured results are shared with the entire organization. This disclosure is expected to further promote consciousness for improved energy efficiency through healthy competition among various departments.

Information System - Designing

Information system can be used for effective and current tracking. A system for tracking performance can range from a simple spreadsheet to detailed databases and IT system. In developing an appropriate tracking system, the following features may be considered:

- Design of tracking system will depend upon the level and scope of information to be tracked and frequency of data collection (daily or weekly or monthly)
- Tracking system must be easy to use, update and maintain
- Tracking system must be used to communicate energy performance to all parts of the organization to motivate change
- Formats must be developed so that they are understandable across the ogranisation; good tracking system should make reporting easy

Evaluate Progress in meeting goals and targets

It is a more formal review of both energy use data and assessing achievement against the set goals and targets. It is the process of comparing overall energy performance, especially goals against the established baselines for assessing energy and cost savings.

Review Action plans

After reviewing the overall energy performance data, it is time to introspect on what worked well and what did not, in order to identify the best practices.

The next step is to understand the factors affecting the results as well as benefits of improved energy performance. Periodic review of energy management initiatives will help energy managers to:

- Measure the effectiveness of projects and programs implemented
- Make informed decision about future energy projects
- Reward individuals and team for accomplishments
- Document additional savings opportunities as well as non-quantifiable benefits

After one cycle of program is completed, the report should be prepared and submitted to the top (senior) management. The results shall be assessed and analyzed and the lesson learned shall be utilized as a feedback in the subsequent plans/programs. Thus, the activities are repeated to form a cyclic movement.

6.7 Recognize Achievements

Providing recognition to those who helped the organisation achieve the results motivates the staff and employees and brings positive exposure to the energy management programs.

a) Internal Recognition

Key steps in internal recognition are:

Recognition levels: the decision about who should receive recognition. Common recognition levels are

Individual – Acknowledges the contribution and accomplishment of specific people

Teams – Recognizes the achievement of teams, departments and other groups

Facility- Rewards the accomplishment or performance of entire facility

Recognition criteria: Criteria might include mention of achievement such as:

- Offered the best energy saving idea
- Achieved the highest energy use reduction
- Increased savings by quantified amount

Determine recognition type: There are a variety of ways to provide recognition and rewards. Forms of recognition can range from formal acknowledgements and certificates, to salary increases and cash bonuses, to simple forms of appreciation such as shields.

Senior management should provide the recognition through formal means such as award ceremony.

b) External recognition

Recognition from a third party can provide validation for an organisation's energy management program. It provides not only satisfaction to those involved in earning the recognition, but also enhances the organisational public image. The solid reputation contributes to organization's competitive advantage by making it more attractive to customers, business lenders and other stakeholders. Getting a National Energy Conservation Award is an example of external recognition.

6.8 Management Tools for Effective Implementation

Development of human capacity is very important to generate new and innovative ideas in-house for promoting energy management. The companies should develop specific training modules related to energy efficiency and energy management as part of its HRD policy. This can be done by encouraging the plant personnel to participate in both internal and external training programs/workshops on these topics. The staff should be encouraged to publish achievements in energy management in both external and internal publications. Management tools covered in this part of chapter are 5S, Kaizen, Small Group Activities, TPM, TQM and ISO 50001.

5S

What is 5S?

5S, abbreviated from the Japanese words **Seiri, Seiton, Seiso, Seiketsu, and Shitsuke**, are simple but effective methods to organize the workplace.

The 5S, translated into English are: **housekeeping, workplace organization, cleanup, maintain cleanliness, and discipline**. They can be defined as follows:

- **Housekeeping.** Separate needed items from unneeded items. Keep only what is immediately necessary item on the shop floor.
- **Workplace Organization.** Organize the workplace so that needed items can be easily and quickly accessed. A place for everything and everything in its place.
- **Cleanup.** Sweeping, washing, and cleaning everything around working area immediately.
- **Cleanliness.** Keep everything clean in a constant state of readiness.
- **Discipline.** Everyone understands, obeys, and practices the rules when in the plant.

Potential Benefits of 5S

Implementing 5S methods in the plant would help the company to reduce waste hidden in the plant, improve the levels of quality and safety, reduce the lead time and cost, and thus, Increase Company's **profit**.

The potential benefits of 5S can be summarized by **PQCDS**:

PQCDS:

- **P -** Increase productivity.
- **Q -** Improve product quality.
- **C -** Reduce manufacturing costs.
- **D -** Ensure on-time delivery.
- **S -** Provide a safe working environment.

Implementation Procedure of 5S

Depending on company's situation, the 5S can be implemented in different manners. However, many companies felt that the following **PDCA** procedure is quite effective:

1. Organize the program committee. **(PLAN)**
2. Develop a plan for each S. **(PLAN)**
3. Publicly announcement the start of the program. **(PLAN)**
4. Provide training and education to employees. **(DO)**
5. Select a day when everybody cleanups his/her own working area. **(DO)**
6. Select a day when everybody organizes his/her own workplace.**(DO)**
7. Evaluate the results of 5S. **(CHECK)**
8. Self-Examination and Take corrected actions. **(ACTION)**

The 5S can be successfully implemented following a generic **PDCA** (Plan -> Do -> Check -> Action) procedure. The relationship between 5S and PDCA can be depicted as in Figure 6.5.

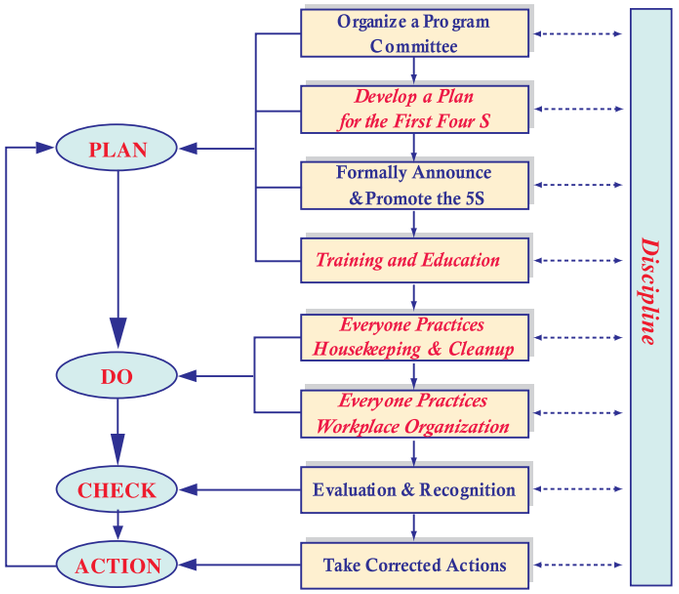

Figure 6.5 Implementing Procedure of 5S

KAIZEN

What is "Kaizen"?

"KAIZEN", is a practice developed by Japanese for increasing productivity. KAIZEN is the Japanese word made up of two components.

KAI – Change
ZEN – Good (for the better)
KAIZEN – Change for the better or continuous improvement.

KAIZEN means continuous improvement involving everyone – Managers and Workers alike. It emphasizes improvement on working standard through small, gradual improvement. Its philosophy assumes that our way of working life, our social life or our human life – deserves to be constantly improved.

Kaizen events

Kaizen events focuses on reducing various forms of wastes and often energy reduction result from projects that focus on an area or a process. For example, a project that was implemented to reduce colouring chemicals in a plastic industry resulted in small changes in plant layout and material flow to its use. This ended up in big reduction in amount of forklift travelled and fuel used in the forklift.

Kaizen events that are intentionally structured for reduction of energy as a primary outcome can be even more powerful. For example, managers have commissioned steam or compressed air leak reduction events where both detection and immediate correction by operators takes place on the spot. These events produce immediate returns and deliver very rapid savings to the operation. More importantly, when done properly, kaizen events really engage employees in such a way that they are enrolled in energy conservation efforts in the future.

How to implement Kaizen?

Step-1: Identification of a problem, i.e. waste, defect or something not working. The operator writes and describes the problem

Step-2: Operator later develops an improvement idea and goes to immediate supervisor

Step-3: Supervisor / Kaizen team members review it and encourage immediate action and fills up the Kaizen form

Step-4: The idea is implemented & checked.

KAIZEN	Kaizen Form No: Date: / /2011
IMPROVEMENT IN ☐ Safety ☐ Housekeeping ☐ Quality ☐ Energy ☐ Cost-savings	No.: Name: Division: Department: Date of Implementation: Signature of Kaizener: Signature of HOD:
BEFORE DESCRIPTION / SKETCH	AFTER DESCRIPTION /SKETCH
DISATVANATGES / PROBLEMS	ADVANTAGES
Implementation Cost (Rs.)	Cost Savings (Rs.)
Approved by Maintenance Dept.:	Approved by User Dept:

Step-5: The operator is rewarded.

Small Group Activities (SGA)

Small Group activities encourage their members to discuss, think, and judge necessary matters based on the facts and data. Without confirming the facts and collecting data, people often make judgments based solely on their experience, intuition, and gut feeling. On the other hand, the scientific way of thinking relies on the facts and data.

To achieve the best results, all employees from top to bottom should be involved in energy management activities. Under this concept, cross-functional team at the shop floor conceptualizes a project, carries out measurement and implements with the help of concerned departments in the plant. Monitoring of its successful operation and actual savings realized are projected. This exercise creates awareness and gives a sense of confidence, ownership and achievement to employees for their contribution in this area. It has been observed that plants using this activity developed a culture of energy savings and the plant has benefited a lot in terms of sustainability of energy savings identified through this process.

Planning and implementation of SGA (Small Group Activities)

(1) Administration of Small Groups and solving Energy Conservation problems
(2) Formation of Small Groups (belonging to the same section, having the same functional skill, depending on the individual problems, acting by fixed members, and so on)
(3) Definition of functions of each group member
(4) Setting the target and the annual program
(5) Preparation for Small Group meetings
(6) Administration of Small Group meetings
(7) Follow-up of Small Group meetings
(8) Summarizing lessons from problems tackled by Small Groups
(9) Reporting and presentation of the problems solved.

TPM

Total productive maintenance (TPM) is method that focuses on optimizing the effectiveness of manufacturing equipment. TPM builds upon established equipment-management approaches and focuses on team-based maintenance that involves employees at every level and function.

What is TPM?

The goal of TPM is to build a robust organisation by maximizing production system efficiency (overall effectiveness).

- TPM addresses the entire production system lifecycle and builds a concrete, shop floor-based system to prevent all losses. It aims to eliminate all accidents, defects, and breakdowns.
- TPM involves all departments from production to development, sales, and administration.
- Everyone participates in TPM, from the top executive to shop floor employees.
- TPM achieves zero losses through overlapping team activities.

Six Big Losses That Lower Equipment Efficiency

Increased equipment operating efficiency reduces energy waste. When machines are optimally tuned to accomplish the desired work, energy inputs are minimum. TPM's emphasis on equipment efficiency can lead to reduced costs, increased productivity, and fewer defects. TPM focuses on the six big losses that lead to equipment inefficiency:

1. Breakdowns
2. Setup and adjustment loss
3. Idling and minor stoppages
4. Reduced speed
5. Defects and rework
6. Start and yield loss

Eradicating the six big losses maximizes the productivity of equipment throughout its lifetime. With proper equipment and system maintenance, facilities can reduce manufacturing process defects and save an estimated 25 percent in energy costs.

Four strategies for integrating energy-reduction efforts into TPM to improve energy and equipment efficiency in any facility are:

- Integrate energy reduction opportunities into autonomous maintenance activities
- Train employees on how to identify energy wastes and how to increase equipment efficiency through maintenance and operations
- Conduct energy kaizen events to make equipment more efficient
- Build energy-efficiency best practices into systems for management of safety, health, and environmental issues

Autonomous Maintenance Improves Energy Efficiency

One distinctive aspect of TPM is *autonomous maintenance*. Autonomous maintenance refers to ongoing maintenance activities operators undertake on their own equipment. Typical activities include: (1) daily inspections, (2) lubrication, (3) parts replacement, (4) simple repairs, (5) abnormality detection, and (6) precision checks. Autonomous maintenance provides an opportunity to integrate process-level energy-reduction strategies into ongoing equipment maintenance.

Many simple energy efficiency best practices can be implemented without extensive analysis or effort. Autonomous maintenance already captures a number of best practices, such as cleaning, proper lubrication, and standardized maintenance practices. Any facility can enhance TPM effectiveness by integrating energy-reduction best practices for specific types of processes into ongoing autonomous maintenance activities.

Checklists such as the *Energy-Reduction Checklists for Combustion, Steam Generation, and Process Heating Systems* to identify opportunities to decrease energy consumption while also increasing equipment efficiency.

Energy Reduction Checklists for Combustion, Steam Generation and Process Heating Systems

Combustion Systems

- Operate furnaces and boilers at or close to design capacity
- Reduce excess air used for combustion
- Clean heat transfer surfaces
- Reduce radiation losses from openings
- Use proper furnace or boiler insulation to reduce wall heat losses
- Adequately insulate air or water-cooled surfaces exposed to the furnace environment and steam lines leaving the boiler
- Install air preheat or other heat recovery equipment

Steam Generation Systems

- Improve water treatment to minimize boiler blowdown
- Optimize deaerator vent rate
- Repair steam leaks
- Minimize vented steam
- Implement effective steam trap maintenance program

Process Heating Systems

- Minimize air leakage into the furnace by sealing openings
- Maintain proper, slightly positive furnace pressure
- Reduce weight of or eliminate material handling fixtures
- Modify the furnace system or use a separate heating system to recover furnace exhaust gas heat
- Recover part of the furnace exhaust heat for use in lower-temperature processes

Total Quality Management (TQM)

TQM is a process for managing quality. TQM is often associated with the phrase - “doing the right things right, first time”. The rejections or failing to meet specifications also involves energy loss, for example, a casting produced with blow holes has to be scraped and which involves considerable energy. Hence TQM can complement an energy management program. The implementation of TQM must involve the followings:

- Involvement of all, from worker to top executive
- Management commitment must be evidently demonstrative.
- Document what you do; then do what you had documented
- Effective strategic planning and information management must be introduced.
- Mission and Vision statement must be written and displayed every-where. These must be the guiding rules to all employees.
- People satisfaction should be the first priority. A satisfied person is motivated to do work in a better way.

- Identification of problem should be the way of life, so that problem-solving may be undertaken as a route of continuous improvement.
- Long-term needs, rather than short-term needs must be given more emphasis to derive major benefits.
- All employees should be committed to adhere to systems and procedures so that a quality culture is a regular affair.

Motivational scheme, regular training and educational scheme should be regular affair to sustain interest in TQM endeavour.

ISO 50001:2011 – Energy Management System (EnMS)

ISO 50001 is based on the management system model of continual improvement which is also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organizations to integrate energy management into their overall efforts to improve quality and environmental management.

Energy Management Sysem enables an organization to take a systematic approach in order to achieve continual improvement of energy performance, energy efficiency, and energy conservation.

ISO 50001:2011 provides a framework of requirements for organizations to:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions about energy use
- Measure the results
- Review how well the policy works, and
- Continually improve energy management.

An energy management system addresses:

- Energy supply
- Measurement
- Documentation and reporting of energy use and
- Procurement and design practices for energy-using equipment, systems, and processes.

ISO 50001 will establish a framework for industrial plants, commercial facilities or entire organizations to manage energy. Targeting broad applicability across national economic sectors, it is estimated that the standard could influence up to 60% of the world's energy use.

The document is based on the common elements found in all of ISO's management system standards, assuring a high level of compatibility with ISO 9001 (quality management) and ISO 14001 (environmental management). ISO 50001 will provide the following benefits:

- A framework for integrating energy efficiency into management practices
- Making better use of existing energy-consuming assets
- Benchmarking, measuring, documenting, and reporting energy intensity improvements and their projected impact on reductions in greenhouse gas (GHG) emissions
- Transparency and communication on the management of energy resources
- Energy management best practices and good energy management behaviours

- Evaluating and prioritizing the implementation of new energy-efficient technologies
- A framework for promoting energy efficiency throughout the supply chain
- Energy management improvements in the context of GHG emission reduction projects.

The ISO 50001 standard is configured as follows:

4.1 General Requirements **4.2 Management Responsibility** **4.3 Energy Policy** **4.4 Planning** 4.4.1 Energy Review / Profile 4.4.2 Legal and Other Requirements 4.4.3 Objectives, Targets and Action Plans	**4.6 Checking Performance** 4.6.1 Monitoring and Measurement 4.6.2 Evaluation of Legal / Other Compliance 4.6.3 Management System Audit 4.6.4 Nonconformities, Corrective, Preventive and Improvement Actions 4.6.5 Control of Records
4.5 Implementation and Operation 4.5.1 Competence, Awareness and Training 4.5.2 Design 4.5.3 Operational control 4.5.4 Documentation requirements 4.5.5 Communication 4.5.6 Purchasing 4.5.7 Contingency planning	**4.7 Review of the Energy Management System by Top Management** 4.7.1 Management Review Inputs 4.7.2 Management Review Outputs

How ISO 50001 will work as a system to enhance energy efficiency?

Example for a cement plant:

Goal

The goal of the company as stated in the Energy Policy

"Reduce energy use per output by 15 per cent, relative to the 2015 base year, by 2017"

Objectives

There can be several objectives to achieve this goal. The objectives could be

(a) Reducing coal consumption by 10% by 2016

(b) Reducing specific energy consumption of clinker from 90 kWh/ton to 85 kWh/ton

Targets

The targets are more specific and imply the actual energy conservation measures to be implemented. The targets could be

Under objective (a), the following are the targets

(a1) Reducing and controlling excess air in the kiln with online oxygen analyser

(a2) Waste heat recovery from clinker cooler exhaust

(a3) Use of waste tyres to partially replace coal firing in the kiln

Under objective (b), the following are the targets

(b1) Replacing inefficient raw mill fan with new energy efficient fan

(b2) Modifying the compressed piping system to reduce pressure drops

(b3) providing VFD drive for dust collector fan in the raw mill

(b4) Replacing pneumatic conveying with bucket elevators for raw meal transport

Typical Action Plan

Objective:	Reducing coal consumption by 10% by 2016		
Target;	Reducing and controlling excess air in the kiln with online oxygen analyser		
Overall Responsibility:	General Manager		
Actions	**Time**	**Responsibility**	**Resources**
Identify vendor	Feb, 2015	Energy Mgr	Rs.5,00,000
Raise Purchase order	Mar, 2015	Purchase Mgr	
Install and Commission	October, 2015	Instrument Mgr	
Monitoring and evaluation	Continuous from October onwards	Energy Mgr	

To simply put it, ISO 50001 is *"saying what you do and doing what you say".* Since action plans are documented and audited during internal and external audits, there will be a commitment and binding in implementation of energy conservation measures and sustaining an effective energy management system.

QUESTIONS

Objective Type Questions

1.	An energy policy provides the _____ for setting performance goal and integrating energy management into an organization's culture. a) budget b) delivery mechanism c) action plan d) foundation
2.	Which one is not a step in energy action planning a) make commitments b) implement action plan c) set goals d) conduct safety audit
3.	Which of the following is not a common normalizing factor in industrial facilities? a) input b) output c) product type d) maintenance cost
4.	Which of the following is a negative force in force field analysis? a) high price of energy b) high energy share of component of production cost c) availability of energy efficient technology d) competing corporate priorities
5.	Which one of the following is not an important duty of a certified energy manager? a) report to BEE and State level designated agencies b) prepare a scheme for efficient use of energy c) establish an improved data recording and analysis d) create knowledge bank on sectoral and national development on energy efficiency technology and information
6.	From the combination below, which is not a key element of a successful energy management program? a) technical ability b) monitoring system & a strategy plan c) security of plant d) top management support
7.	Which among the following would be of importance in the success of an energy management programme? a) communication b) awareness c) motivation d) all of the above
8.	The proposed international standard for Energy Management System is a) ISO 9001 b) ISO 14000 c) ISO 14001 d) ISO 50001
9.	An energy management system addresses a) energy supply b) measurement c) procurement and design d) all of the above
10.	Publishing a formal statement of energy policy that can be used to define company activities in energy matters is the role of _____ a) top management b) middle management c) energy auditor d) energy manager

Short Type Questions	
S-1.	Explain how autonomous maintenance can improve energy efficiency?
S-2.	Explain ways by which employees can be motivated on energy management?
S-3.	What is the need for normalizing energy data?
S-4.	Write short notes on ISO 50001.
S-5.	What are the various ways of recognizing employees for their achievements in energy management?
Long Type Questions	
L-1.	What is force field analysis and how it can be useful for energy action planning?
L-2.	List atleast 5 duties and 3 responsibilities of an energy manager.

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Chapter 7

Financial Management

Learning Objectives

In this chapter you will learn about

- Need for investment appraisal and criteria
- Simple Payback period
- Return on investment
- Net present value
- Internal rate of return
- Sensitivity analysis
- Financing options
- ESCO model

7. FINANCIAL MANAGEMENT

Investment - Need, Appraisal and Criteria, Financial analysis techniques - Simple payback period, Return on investment, Net present value, Internal rate of return, Cash flows, Risk and sensitivity analysis, Financing options, Energy performance contracts and role of ESCOs

7.1 Introduction

Energy Projects are very important to the economy and environment. In case of energy conservation projects—the more the number, the better it is for the environment. It is important to justify any capital investment project by carrying out a financial appraisal. However, the biggest constraint in increasing the number of energy projects is the lack of finance. Alternative finance arrangements can overcome the "initial cost" obstacle, allowing firms to implement more energy management proposals. However, many energy managers are either unaware or have difficulty in understanding the variety of financial arrangements available to them. Most of the energy managers and auditors use simple payback analysis to evaluate projects, which do not reveal the added value of after-tax benefits. Sometimes energy managers do not implement Energy Management Proposals because financial terminology and contractual details intimidate them. The financial issues associated with the capital investment in energy saving projects are investigated in this chapter.

7.2 Investment Need, Appraisal and Criteria

When planning an energy efficiency or energy management project, the investment involved should be considered. The need for investments in energy conservation can arise for installing new equipment, improving process, providing staff training, and implementing or upgrading energy information system.

Therefore, as with any type of investment, energy management proposals should show the likely return on any capital that is invested. Consider a case of an energy auditor or consultant who advises the senior management of an organization that capital should be invested in new boiler plant. Inevitably, the management of the organization would enquire:

- How much will the proposal cost?
- How much money will be saved by the proposal?

These are relevant questions as the energy project is only one of many potential projects from which top management may choose only a few to implement. It is the job of senior management to invest capital where it is going to obtain the greatest return. Management normally demand higher rate of return from energy projects than core or direct profit-making investments.

The information on costs involved in a project and potential returns is not easily obtained. The capital value of equipment usually decreases with time and it often requires more maintenance as it gets older. If money is borrowed from a bank to finance a project, then interest will have to be paid on the loan. Inflation too will influence the value of any future energy savings that might be achieved. It is important that cost appraisal process allows for all these factors with the aim of determining which investment

should be undertaken in order to optimize the benefits achieved. To this end a number of accounting and financial appraisal techniques have been developed which help managers make correct and objective decisions.

To gain acceptance of top management, top management should be appraised on the size of energy problem technical and good housekeeping measures available to reduce waste. Before making any investment, it should be ensured that best performance is realized from existing plant and equipment, energy charges are set at the lowest possible tariffs, best energy forms (fuels or electricity) are used as efficiently as possible and that good housekeeping practices are being regularly practiced.

The benefits of energy management projects should be projected to senior management not only as energy savings, but also in terms of lower operational costs, low risk/reward ratio, reduced environmental cost, improved productivity, better product quality or enhanced quality of service and potential to improve the company's share value. Most importantly, systematic financial management approach has to be followed to rate various investment options against anticipated savings.

7.3 Financial Analysis Techniques

In most respects, investment in energy efficiency is not different from any other area of financial management. So when the organization first decides to invest in increasing its energy efficiency, it should apply exactly the same criteria to reduce its energy consumption as it applies to all its other investments. A faster or more attractive rate of return on investment in energy efficiency should not be demanded.

The basic criteria for financial investment appraisal include:

- **Payback period –** is a measure of how long it will be before the investment recovers itself. This can determine how long the financing term needs to be there.
- **Net Present Value (NPV) and Cash Flow –** are measures that allow financial planning of the project taking into account streams of money inflow and outflow over a period of time. These measures provide the company with all the information needed to incorporate energy efficiency projects into the corporate financial system
- **Return on Investment (ROI) and Internal Rate of Return (IRR) –** are measures that allow comparison with other investment options

Payback Period

The simplest technique which can be used to appraise a proposal is payback analysis. The payback period can be defined as the time (number of years) required to recover the initial investment (capital cost), considering only the Annual Net Savings (Yearly benefits-Yearly costs). Once the payback period has ended, all the project capital costs will have been recovered and any additional cost savings achieved can be seen as clear 'profit'.

The shorter the payback period, the more attractive the project becomes. The length of the maximum permissible payback period is a matter of company choice.

The simple payback period can be calculated using the equation

$$\textbf{Simple Payback period} = \frac{\textbf{Capital cost}}{\textbf{Annual net savings}}$$

Annual Net savings is the cost savings achieved after all the operational costs have been met.

The word 'simple' is used as a prefix to the term 'payback period' to denote that time value of money is not considered in its calculation.

Example 7.1: Simple Payback period

A cogeneration system installation is expected to reduce a company's annual energy bill by Rs. 23 Lakhs. If the capital cost of the new cogeneration installation is Rs. 90 Lakhs, and the annual maintenance and operating costs are Rs. 5 Lakhs, what will be the expected payback period for the project?

Simple payback period = $\frac{90}{23\text{-}5}$

= 5 years

Advantages

A widely used investment criterion, the payback period seems to offer the following advantages:

- It is simple, both in concept and application. Obviously a shorter payback generally indicates a more attractive investment. It does not use tedious calculations.
- It favours projects, which generate substantial cash inflows in earlier years, and discriminates against projects, which bring substantial cash inflows in later years but not in earlier years.

Limitations of payback period

- The payback period does not consider savings that are accrued after the payback period has finished (it favours projects which brings substantial cash inflows in earlier years and discriminates against projects which bring substantial cash inflows in later years).

Example 7.2: Drawback of payback period

For example consider the cash flows of two projects, A and B:

Investment	Rs. (100,000)	Rs. (100,000)
Savings in Year	**Cash Flow of A**	**Cash flow of B**
1	50,000	20,000
2	30,000	20,000
3	20,000	20,000
4	10,000	40,000
5	10,000	50,000
6	-	60,000

The payback criteria prefer Project A which has a payback period of 3 years, in comparison to Project B which has a payback period of 4 years, even though Project B has very substantial cash inflows in years 5 and 6.

- Simple payback period does not consider the time value of money i.e. money which is invested would accrue interest as time passes.
- Cash inflows, in the simple payback calculation, are simply added without suitable discounting. This violates the most basic principle of financial analysis, which stipulates that cash flows occurring at different points of time can be added or subtracted only after suitable compounding/ discounting.

Return on Investment (ROI)

ROI expresses the "annual return" expected from a project as a percentage of capital cost or initial investment. ROI is an inverse of payback period.

$$\textbf{ROI} = \frac{\textbf{Annual net cash flow}}{\textbf{Capital cost}} \times \textbf{100}$$

In comparing projects, ROI does not require similar project life or capital cost for comparison. ROI must always be higher than cost of money (interest rate) so as to make the project attractive; the greater the return on investment better is the investment.

Example 7.3: ROI

An outlay of Rs.100,000 for equipment is expected to provide an after-tax cash flow of Rs. 25,000 over a period of six years, without significant annual fluctuations. What is the return on investment?

$$\text{ROI} = \frac{\text{Average annual operating cash flow}}{\text{Net investment}} = \frac{25{,}000}{100{,}000} \times 100$$

$$= 25\%$$

Advantages

- Simple method and easy to calculate
- Returns expressed as percentage makes it easier to evaluate against the borrowing interest

Limitations of ROI

- It does not take into account the time value of money.
- It also does not account for the variable nature of annual net cash inflows. The 25 percent return indicated in the Example would be economically valid only if the investment yields Rs. 25,000 per year *in perpetuity* -not a very realistic condition!

Time Value of Money

A project usually entails an investment for the initial cost of installation, called the capital cost, and a series of annual costs and/or cost savings (i.e. operating, energy, maintenance, etc.) throughout the life of the project. To assess project feasibility, all these present and future cash flows must be equated to a common basis. The problem with equating cash flows which occur at different times is that the value of money changes with time. The method by which these various cash flows are related is called ***discounting***, or the ***present value*** concept.

For example, if money can be deposited in the bank at 10% interest, then a Rs.100 deposit will be worth Rs.110 in one year's time. Thus the Rs.110 in one year is a future value equivalent to the Rs.100 present value.

In the same manner, Rs.100 received one year from now is only worth Rs.90.91 in today's money (i.e. Rs.90.91 plus 10% interest equals Rs.100). Thus Rs.90.91 represents the present value of Rs.100 cash flow occurring one year in the future. If the interest rate were something different than 10%, then the equivalent present value would also change. The relationship between present and future value is determined as follows:

$FV = NPV\ (1 + i)^n$ or $NPV = FV / (1+i)^n$

Where, *FV = Future value of the cash flow*
NPV= Net Present Value of the cash flow
i = Interest or discount rate
n = Number of years in the future

Net Present Value Method

The net present value method considers the time value of money. This is done by equating future cash flow to its current value today, or in other words by determining the *present value* of any future cash flow. The *present value* is determined by using an assumed interest rate, usually referred to as a discount rate. Discounting is the opposite process to compounding. Compounding determines the future value of present cash flows, whereas discounting determines the *present value* of future cash flows.

The *net present value* method calculates the *present value* of all the yearly cash flows (i.e. capital costs and net savings) incurred or accrued throughout the life of a project and summates them. As a matter of convention, costs are represented as negative values and savings as positive values. The sum of all the present values is known as the *net present value* (NPV). The higher the *net present value*, the more attractive is the proposed project.

The net present value (NPV) of a project is equal to the sum of the present values of all the cash flows associated with it. Symbolically,

$$NPV = \frac{CF_0}{(1+\kappa)^0} + \frac{CF_1}{(1+\kappa)^1} + \cdots + \frac{CF_n}{(1+\kappa)^n} = \sum_{t=0}^{n} \frac{CF_t}{(1+\kappa)^t}$$

Where NPV = Net Present Value

CF_t = Cash flow occurring at the end of year 't' (t=0,1,….n). (As per our convention, net savings or inflows are represented by + sign and net costs or outflows are represented by – sign. Since capital investment is an outflow, it will be treated as negative (-) as per our convention.)

n = life of the project

k = Discount rate

The discount rate (k) employed for evaluating the present value of the expected future cash flows should reflect the risk of the project.

Hence the decision rule associated with the net present value criterion is: "Accept the project if the net present values is positive and reject the project if the net present value is negative". A negative net present value indicates that the project is not achieving the return standard and thus will cause an economic loss if implemented. A zero NPV is value neutral.

The net present value takes into account the time value of money and it considers the cash flow stream in entire project life.

Example 7.4: NPV

Using the *net present value* analysis technique, evaluate the financial merits of the two proposed projects shown in the table. The annual discount rate is 8% for each project.

	Project 1	Project 2
Capital cost (Rs.)	30000	30000
Year	**Net annual saving (Rs.)**	**Net annual saving (Rs.)**
1	+6000	+6600
2	+6000	+6600
3	+6000	+6300
4	+6000	+6300
5	+6000	+6000
6	+6000	+6000
7	+6000	+5700
8	+6000	+5700
9	+6000	+5400
10	+6000	+5400
Total net savings at end of 10^{th} year	**+60000**	**+60000**

For Project 1

$$NPV = -\frac{30000}{(1+0.08)^0} + \frac{6000}{(1+0.08)^1} + \frac{6000}{(1+0.08)^2} + \frac{6000}{(1+0.08)^3} + \frac{6000}{(1+0.08)^4}$$

$$+ \frac{6000}{(1+0.08)^5} + \frac{6000}{(1+0.08)^6} + \frac{6000}{(1+0.08)^7} + \frac{6000}{(1+0.08)^8} + \frac{6000}{(1+0.08)^9} + \frac{6000}{(1+0.08)^{10}}$$

= - 30000 x 1 + 6000 x 0.926 + 6000 x 0.857 + 6000 x 0.794 + 6000 x 0.735 + 6000 x 0.681 + 6000 x 0.630 + 6000 x 0.583 + 6000 x 0.540 + 6000 x 0.500 + 6000 x 0.463

= + 10254

For Project 2

$$NPV = -\frac{30000}{(1+0.08)^0} + \frac{6600}{(1+0.08)^1} + \frac{6600}{(1+0.08)^2} + \frac{6300}{(1+0.08)^3} + \frac{6300}{(1+0.08)^4}$$

$$+ \frac{6000}{(1+0.08)^5} + \frac{6000}{(1+0.08)^6} + \frac{5700}{(1+0.08)^7} + \frac{5700}{(1+0.08)^8} + \frac{5400}{(1+0.08)^9} + \frac{5400}{(1+0.08)^{10}}$$

= - 30000 x 1 + 6600 x 0.926 + 6600 x 0.857 + 6300 x 0.794 + 6300 x 0.735 + 6000 x 0.681 + 6000 x 0.630 + 5700 x 0.583 + 5700 x 0.540 + 5400 x 0.500 + 5400 x 0.463

= + 10867

For a 10-year life-span, the net present value for project 1 is Rs. 10,254, while for project 2 it is Rs. 10867 Therefore project 2 is preferential proposal.

The whole credibility of the net present value depends on a realistic prediction of discount rate which could often be unpredictable. It is prudent to set the discount rate slightly above the interest rate at which the capital for the project is borrowed.

Advantages

The net present value criterion has considerable merits.

- It takes into account the time value of money.
- It considers the cash flow stream in its project life.

Internal Rate of Return Method

By setting the net present value of an investment to zero (the minimum value that would make the investment worthwhile), the discount rate can be computed. The internal rate of return (IRR) of a project is the discount rate, which makes its net present value (NPV) equal to zero. It is the discount rate in the equation:

$$0 = -\frac{CF_0}{(1+k)^0} + \frac{CF_1}{(1+k)^1} + \text{- - -} + \frac{CF_n}{(1+k)^n} = \sum_{t=0}^{n} \frac{CF_t}{(1+k)^t}$$

Where, CF_t = cash flow at the end of year "t"
k = discount rate
n = life of the project.

CFt value will be negative if it is expenditure and positive if it is savings.

If this discount rate is greater than current interest rate, the investment is sound.

This procedure, like net present value, can also be used to compare alternatives. The criterion for selection among alternatives is to choose the investment with the highest rate of return. The calculation procedure for determining IRR is tedious and usually requires a computer spreadsheet. The IRR function formula is available in Excel and can be used in practice. However, it is important to get acquainted with the fundamental procedure of determining the IRR. Determining IRR is an iterative process requiring guesses and approximations until a satisfactory answer is derived.

Example 7.5: IRR (Example of iterative procedure to estimate the IRR)

A proposed project requires an initial capital investment of Rs. 20,000. The cash flows generated by the project are shown in the table below:

Investment	Rs. 20,000
Saving in Year	Cash flow
1	6000
2	5500
3	5000
4	4500
5	4000
6	4000

The cost of capital (discount rate), κ, for the firm is 8 per cent.

The net present value of the proposal is:

$$NPV = -\frac{20000}{(1+0.08)^0} + \frac{6000}{(1+0.08)^1} + \frac{5500}{(1+0.08)^2} + \frac{5000}{(1+0.08)^3} + \frac{4500}{(1+0.08)^4} + \frac{4000}{(1+0.08)^5} + \frac{4000}{(1+0.08)^6}$$

$$= -20000 \times 1 + 6000 \times 0.926 + 5500 \times 0.857 + 5000 \times 0.794 + 4500 \times 0.735 + 4000 \times 0.681 + 4000 \times 0.630$$

$$= 2791$$

The discount rate has to be increased to bring NPV to zero.

Increasing the discount rate to 12%,

$$NPV = -\frac{20000}{(1+0.12)^0} + \frac{6000}{(1+0.12)^1} + \frac{5500}{(1+0.12)^2} + \frac{5000}{(1+0.12)^3} + \frac{4500}{(1+0.12)^4} + \frac{4000}{(1+0.12)^5} + \frac{4000}{(1+0.12)^6}$$

$$= -20000 \times 1 + 6000 \times 0.893 + 5500 \times 0.797 + 5000 \times 0.712 + 4500 \times 0.636 + 4000 \times 0.567 + 4000 \times 0.507$$

$$= 495$$

Further increasing the discount rate to 16%

$$NPV = -\frac{20000}{(1+0.16)^0} + \frac{6000}{(1+0.16)^1} + \frac{5500}{(1+0.16)^2} + \frac{5000}{(1+0.16)^3} + \frac{4500}{(1+0.16)^4} + \frac{4000}{(1+0.16)^5} + \frac{4000}{(1+0.16)^6}$$

= - 20000 x 1 + 6000 x 0.862 +5500 x 0.743 + 5000 x 0.641 + 4500 x 0.552 + 4000 x 0.476 + 4000 x 0.410

= -1508.5

For a discount rate of 13%

$$NPV = -\frac{20000}{(1+0.13)^0} + \frac{6000}{(1+0.13)^1} + \frac{5500}{(1+0.13)^2} + \frac{5000}{(1+0.13)^3} + \frac{4500}{(1+0.13)^4} + \frac{4000}{(1+0.13)^5} + \frac{4000}{(1+0.13)^6}$$

= - 20000 x 1 + 6000 x 0.885 +5500 x 0.783 + 5000 x 0.693 + 4500 x 0.613 + 4000 x 0.543 + 4000 x 0.480

= - 65

It can be clearly seen that the discount rate which results in the net present value being zero lies somewhere between 12% and 13%. It is closer to 13%.

The exact internal rate of return can be found by interpolation or plotting the net present value on a graph as shown in Figure 7.1.

By interpolation Method

NPV at 13% = -65

NPV at 12% = +495

$$IRR = \text{Lower rate} + \frac{\text{NPV at lower rate x (Higher rate-lower rate)}}{(\text{NPV at lower rate} - \text{NPV at higher rate})}$$

$$IRR = 12 + \frac{495 \times (13-12)}{495 - (-65)}$$

= 12.88 %

By Graphical Method

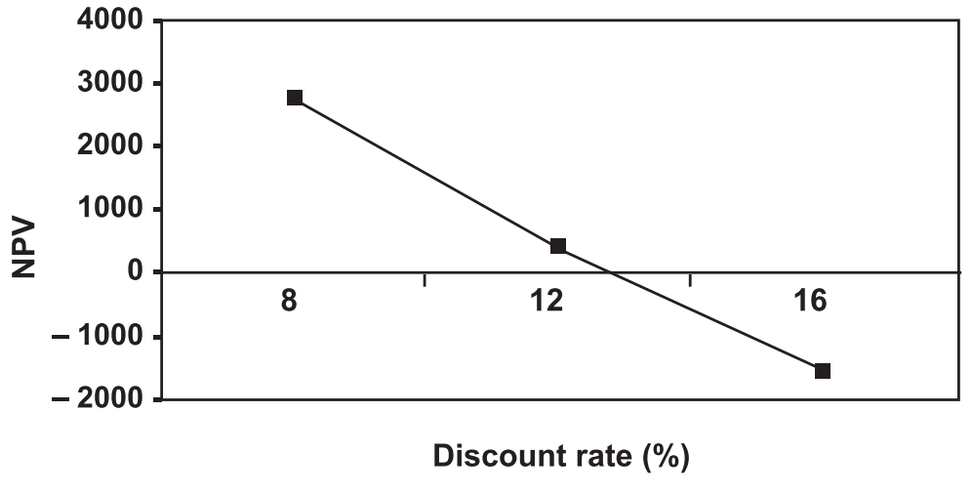


Figure 7.1 NPV versus Discount Rate

The Figure 7.1 shows the IRR for the project from graph is around 12 .88 %.

Advantages

A popular discounted cash flow method, the internal rate of return criterion has several advantages:

- It takes into account the time value of money.
- It considers the cash flow stream in its entirety.
- It makes sense to businessmen who prefer to think in terms of rate of return and find an absolute quantity, like net present value, somewhat difficult to work with.

Limitations

- The internal rate of return figure cannot distinguish between lending and borrowing and hence a high internal rate of return need not necessarily be a desirable feature.

Comparison between *Net Present Value* and *Internal Rate of Return*

Although, they look similar, there is an important difference between the two methods.

In the net present value calculation, NPV of the project is determined by assuming that the discount rate (cost of capital) is known. In the internal rate of return calculation, we set the net present value equal to zero and determine the discount rate (internal rate of return), which satisfies this condition.

The *net present value* method is essentially a comparison tool which enables number of different projects to be compared while the *internal rate of return* method is designed to assess whether or not a single project will achieve a target rate of return.

7.4 Cash Flow

Capital Investment Considerations

To judge the attractiveness of any investment, we must consider the following four elements involved in the decision:

- ✓ Initial capital cost or net investment
- ✓ Net operating cash inflows (the potential benefits)
- ✓ Economic life (time span of benefits)
- ✓ Salvage value (any final recovery of capital)

Initial capital cost or net investment

When companies spend money, the outlay of cash can be broadly categorized into one of two classifications; expenses or capital investments. Expenses are generally those cash expenditures that are routine, ongoing, and necessary for the ordinary operation of the business. Capital investments, on the other hand, are generally more strategic and have long term effects. Decisions made regarding capital investments are usually made by senior management and carry with them additional tax consequences as compared to expenses.

The capital investments usually require a relatively large initial cost. The initial cost may occur as a single expenditure or occur over a period of several years. Generally, the funds available for capital investments projects are limited.

Initial capital costs include all costs associated with preparing the investment for service. This includes purchase cost as well as installation and preparation costs. Initial costs are usually non-recurring during the life of an investment.

Net operating cash inflows

The benefits (revenues or savings) resulting from the initial cost for a capital investment occur in the future, normally over a period of years. As a rule, the cash flows which occur during a year are generally summed and regarded as a single end-of-year cash flow. Annual expenses and revenues are the recurring costs and benefits generated throughout the life of the investment after adjusting for applicable taxes and effects of depreciation. Periodic replacement and maintenance costs are similar to annual expenses except that they do not occur annually.

Economic life

The period between the initial cost and the last future cash flow is the life cycle or life of the investment.

Salvage value

The salvage (or terminal) value of an investment is the revenue (or expense) attributed to disposing of the investment at the end of its useful life. If substantial recovery of capital from eventual disposal of assets at the end of the economic life, these estimated amounts have to be made part of the analysis. Such recoveries can be proceeds from the sale of facilities and equipment (beyond the minor scrap value), as well as the release of any working capital associated with the investment.

Cash Flow Diagrams

A convenient way to display the revenues (savings) and costs associated with an investment is a *cash flow diagram*. By using a cash flow diagram, the timing of the cash flows is clear and the chances of properly applying time value of money concepts are increased.

The economic life establishes the time frame over which the cash flows occur first. This establishes the horizontal scale of the cash flow diagram. This scale is divided into time periods which are frequently, but not always, years. Individual outlays or receipts are indicated by drawing vertical lines appropriately placed along the time scale.

Upward directed lines indicate cash inflow (revenues or savings) while downward directed lines indicate cash outflow (costs) as a matter of convention. Figure 7.2 illustrates a cash flow diagram.

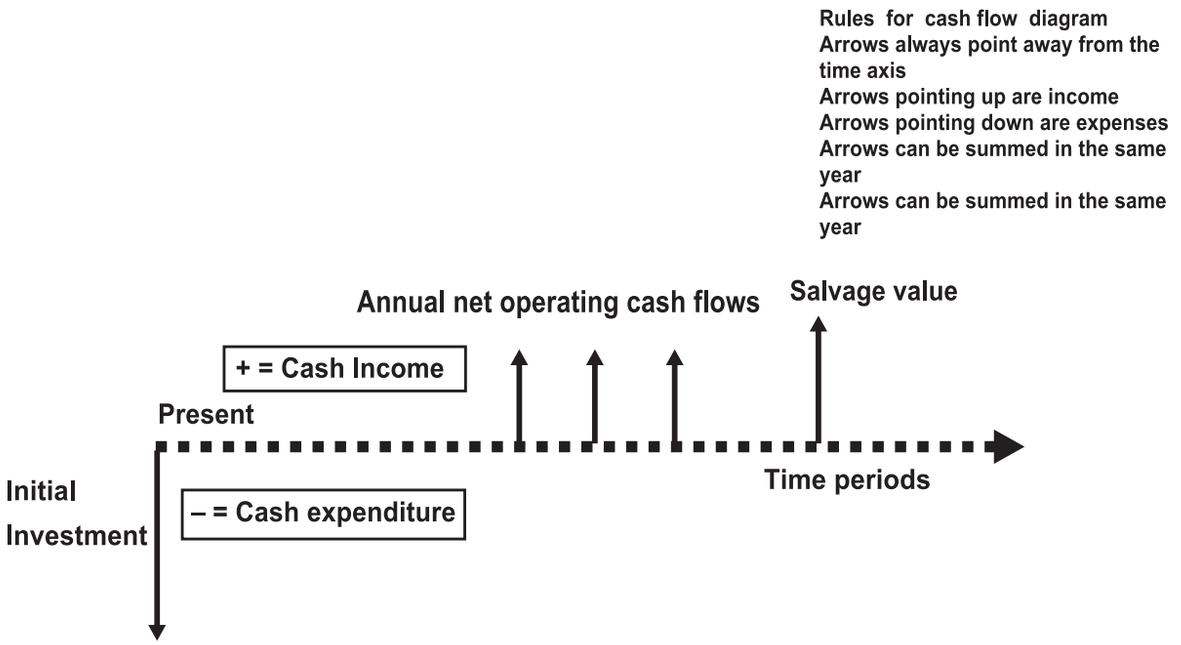


Figure 7.2 Typical Cash Flow Diagram for an Investment

Although cash flow diagrams are simply graphical representations of income and outlay, they should exhibit as much information as possible. The requirements for a good cash flow diagram are completeness, accuracy, and legibility.

7.5 Sensitivity and Risk Analysis

Many of the cash flows in the project are based on assumptions that have an element of uncertainty. The cash flows such as capital cost, energy cost savings, maintenance costs can usually be estimated fairly accurately. Even though these costs can be predicted with some certainty, it should always be remembered that they are only estimates. Cash flows in future years normally contain inflation components and project life itself can vary significantly.

Sensitivity analysis is an assessment of risk. Because of the uncertainty in assigning values to the analysis, it is recommended that a sensitivity analysis be carried out - particularly on projects where the feasibility is marginal. How sensitive is the project's feasibility to changes in the input parameters? What if one or more of the factors in the analysis is not as favourable as predicted? How much would it have to vary before the project becomes unviable? What is the probability of this happening?

Suppose, a feasible project is based on energy cost saving that escalates at 10% per year, but a sensitivity analysis shows the break-even is at 9% (i.e. the project becomes unviable if the inflation of energy cost falls below 9%). There is a high degree of risk associated with this project.

Many of the computer spreadsheet programs have built-in "*what if*" functions that make sensitivity analysis easy. If carried out manually, the sensitivity analysis can become laborious - reworking the analysis many times with various changes in the parameters.

Sensitivity analysis is undertaken to identify those parameters that are both uncertain and for which the project decision, taken through the NPV or IRR, is sensitive. Switching values showing the change in a variable required for the project decision to change from acceptance to rejection are presented for key variables and can be compared with post evaluation results for similar projects. For large projects and those close to the cut-off rate, a quantitative risk analysis incorporating different ranges for key variables and the likelihood of their occurring simultaneously is recommended. Sensitivity and risk analysis should lead to improved project design, with mitigation actions against major sources of uncertainty involved.

The various micro and macro factors that are considered for the sensitivity analysis are listed below.

Micro factors

- ✓ Operating expenses (various expenses items)
- ✓ Capital structure
- ✓ Costs of debt, equity
- ✓ Changing of the forms of finance e.g. leasing
- ✓ Changing the project life

Macro factors

Macro economic variables are the variable that affects the operation of the industry of which the company operates. They cannot be changed by the firm's management. Macro economic variables, which affect projects, include among others:

- ✓ Changes in interest rates
- ✓ Changes in the tax rates
- ✓ Changes in the accounting standards e.g. methods of calculating depreciation
- ✓ Changes in depreciation rates
- ✓ Extension of various government subsidized projects e.g. rural electrification
- ✓ General employment trends e.g. if the government changes the salary scales
- ✓ Imposition of regulations on environmental and safety issues in the industry
- ✓ Energy Price change
- ✓ Technology changes

7.6 Financing Options

Capital investing requires a source of funds. For large companies multiple sources may be employed. The process of obtaining funds for capital investment is called financing. The various conventional financing options are:

- ✓ Debt financing
- ✓ Equity financing
- ✓ Retained earnings
- ✓ Capital lease
- ✓ True lease
- ✓ Performance contracting

Debt financing

Debt financing involves borrowing and utilizing money which is to be repaid at a later point in time. Interest is paid to the lending party for the privilege of using the money. The company owns the equipment and this arrangement is good for long-term use of equipment. The borrower is simply obligated to repay the borrowed funds plus accrued interest according to a repayment schedule. Car loans and mortgage loans are two examples of this type of financing.

The two primary sources of debt capital are loans and bonds. The cost of capital associated with debt financing is relatively easy to calculate since interest rates and repayment schedules are usually clearly documented in the legal instruments controlling the financing arrangements. An added benefit to debt financing under current tax laws is that the interest payments on debt capital are tax deductible. However, in case of debt financing it is the company that takes all the risk and must install and manage the project.

Equity financing

Under equity financing the lender acquires an ownership (or equity) position within the borrower's organization. As a result of this ownership position, the lender has the right to participate in the financial success of the organization as a whole. The two primary sources of equity financing are stocks and retained earnings.

The cost of capital for stocks is higher than the cost of capital for debt financing. Apart from higher profit sharing, this is also partially attributable to the fact that interest payments are tax deductible while stock dividend payments are not.

Retained earnings

Retained earnings are the accumulation of annual earnings surpluses that a company retains within the company's coffers rather than paying out to the stockholders as dividends. Although these earnings are held by the company, they truly belong to the stockholders and hence the same cost of capital for stock is applied.

Capital lease

Capital lease allows for lower cost of capital with third-party participation. It is a mid-way between pure debt and pure equity financing.

True lease

True lease allows use of equipment without ownership risks, offers reduced risk of poor performance, service, equipment obsolescence etc. and is particularly suitable for short-term use of equipment. Lease payments are tax deductible. No depreciation tax benefits are available and ownership does not occur even at the end of lease period.

If the project is to be financed externally, one of the attractive options for many organizations is the use of energy performance contracts delivered by energy service companies, or ESCOs.

7.7 Energy Performance Contracting and Role of ESCOs

What are ESCOs?

ESCOs are usually companies that provide a complete energy project service, from assessment to design to construction or installation, along with engineering and project management services, and financing.

Energy Performance contracting is a unique arrangement that allows the industry to make necessary improvements in energy efficiency while investing very little money up-front. The contractor usually assumes responsibility for purchasing and installing the equipment, as well as maintenance throughout the contract. But the unique aspect of performance contracting is that the contractor is paid based on the performance of the installed equipment. Only after the installed equipment actually reduces expenses does the contractor get paid. Energy service companies (ESCOs) typically serve as contractors within this line of business.

This aspect of '*payment-on-performance'* removes the incentive to "cut corners" on construction or other phases of the project, as with conventional contracting. In fact, often there is an incentive to exceed savings estimates. For this reason, performance contracting usually entails a more "facility wide" scope of work (to find extra energy savings), than loans or leases on particular equipment.

With an industry-wide scope, many improvements can occur at the same time. For example, lighting and air conditioning systems can be upgraded at the same time. In addition, the indoor air quality can be improved. With a comprehensive industry management approach, a "multiplier effect" on cost reduction is possible. For example, if industry improvements create a safer and higher quality environment for workers, productivity could increase.

Depending on the company's capability to manage the risks (equipment performance, financing, etc.) the company will delegate some of these responsibilities to the ESCO. In general, the amount of risk assigned to the ESCO is directly related to the percent savings that must be shared with the ESCO.

For example, a lighting retrofit has a high probability of producing the expected cash flows, whereas a completely new process does not have the same "time tested" reliability. If the in-house energy management team cannot manage this risk, performance contracting may be an attractive alternative.

Types of Performance Contracting

There are a few common types of contracts. The ESCO will usually offer the following options:

- Fixed fee
- Shared savings
- Guaranteed savings

In **fixed fee**, ESCO conducts an audit, designs the project and either assists the customer to implement the project or simply advises the customer for a fixed lump-sum fee. In the fixed fee contract, the ESCO bears less risk compared to a savings based fee payment because their fee does not depend directly on the amount of the achieved savings.

In **shared savings**, ESCO designs, finances and implements the project, verifies energy savings and shares an agreed percentage of the actual energy savings over a fixed period with the customer. Percent energy savings contracts are agreements that basically share energy savings between the host and the ESCO. The more energy saved, the higher the revenues to both the parties.

A combination of part- fixed fee and part- shared savings is practiced as well.

In **guaranteed savings**, ESCO designs and implements the project but does not finance it, although it may arrange for or facilitate financing. The ESCO guarantees that the energy savings bill be sufficient to cover debt service payments.

Obviously, energy managers would prefer the options with "guaranteed savings." However this extra security (and risk to the ESCO) usually costs more. Percent energy savings contracts are agreements that basically share energy savings between the host and the ESCO. The more energy saved, the higher the revenues to both the parties.

Drawbacks of ESCOs

Performance contracting does have some drawbacks. In addition to sharing the savings with an ESCO, the tax benefits of depreciation and other economic benefits must be negotiated. Whenever large contracts are involved, there is reason for concern. Many industries feel that dealing with an ESCO would be too confusing or complicated. Some feel that with complex contracts, there may be more margins for error. Therefore, it is critical to choose an ESCO with a good reputation and experience within the types of facilities that are involved.

Performance Contract: Pros & Cons

"Pros"

- allows use of equipment with reduced installation /operational risks and reduced risk of poor performance, service, equipment obsolescence, etc., and
- allows host to focus on its core business objectives

"Cons"

- potentially binding contracts, legal expenses and increased administrative costs and
- host must share project savings

In some contracts, the ESCOs provide a guarantee for the savings that will be realized, and absorb the cost if real savings fall short of this level. Typically, there will be a risk management cost involved in the contract in these situations. Insurance is sometimes attached, at a cost, to protect the ESCO in the event of a savings shortfall.

What is Depreciation?

Most assets used in the course of a business decrease in value over time. Tax law permits reasonable deductions from taxable income to allow for this. These deductions are called depreciation allowances. To be depreciable, an asset must meet three primary conditions: (1) it must be held by the business for the purpose of producing income, (2) it must wear out or be consumed in the course of its use, and (3) it must have a life longer than a year.

Role of ESCOs

Through the years, ESCO services have become more varied. It has become a customer-driven industry and the customer typically has a selection of ESCO services from which to choose (Figure 7.3). Services offered by an ESCO usually include:

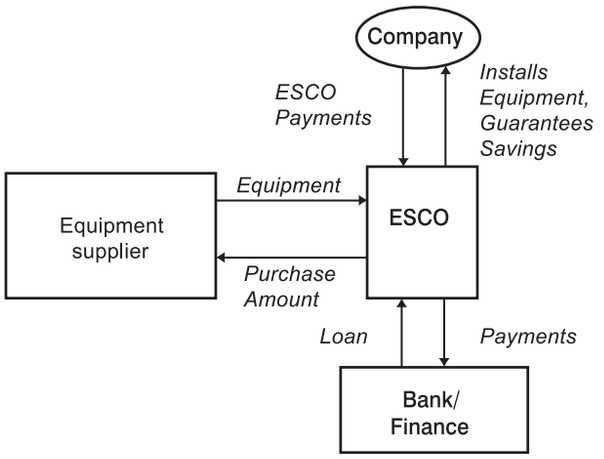


Figure 7.3 Role of ESCO

- ✓ An investment grade energy audit to identify energy and operational savings opportunities, assess risks, determine risk management/ mitigating strategies, and calculate cost-effectiveness of proposed measures over time;
- ✓ Financing from its own resources or through arrangements with banks or other financing sources;
- ✓ The purchase, installation and maintenance of the installed energy efficient equipment; possibly maintenance on all energy-consuming equipment;
- ✓ New equipment training of operations and maintenance (O&M) personnel;
- ✓ Training of O&M personnel in energy-efficient practices;
- ✓ Monitoring of the operations and energy savings, so reduced energy consumption and operation costs persist;
- ✓ Measurement and savings verification; and
- ✓ A guarantee of the energy savings to be achieved.

Benefits to Industry

- ✓ An immediate upgrade of facilities and reduced operating costs— without any initial capital investment;
- ✓ Access to the ESCO's energy efficiency expertise.

- ✓ Positive cash flow—most projects generate savings that exceed the guarantee;
- ✓ The opportunity to use the money, which would have been used for required upgrades or replacements to meet core business needs;
- ✓ Improved and more energy-efficient operations and maintenance;
- ✓ Several normal business risks are assumed by the ESCO, including the guaranteed performance of the new equipment for the life of the contract (not just through a warranty period);
- ✓ A more comfortable, productive environment; and
- ✓ Services paid for with the money which the customer would otherwise have paid to the utilities for wasted energy.

7.8 Developing a Typical ESCO Contract

a) Self-assessment by organization to assess motivation for energy efficiency projects
b) Establish goals for the EE project
c) Conduct Feasibility study for EE project
d) Determine suitable EE project contract and financing
e) Enter into Energy Performance Contract (EPC) to initiate investment grade energy audit. (IGA)

- ✓ The contract will have rewards and penalties built into it in the form of various guarantees. Contract duration will affect the project risk. The longer the duration, the higher is the risk and uncertainty of the contract.
- ✓ Organization can contract with ESCO in one of three payment mechanism: a) fixed fee; b) shared savings; c) guaranteed savings.

f) Conduct of IGA and Implementation of commercially feasible energy efficiency measures

- ✓ An investment grade energy audit is the process of conducting an energy audit to identify efficiency opportunities, and translating the technical findings into financial terms to present it as a bankable project capable of securing a loan.
- ✓ Services of ESCO may be engaged in single step or two steps. In single step process, ESCO conducts the IGA and effects energy savings by implementing recommended measures. In two step process, organization contracts the ESCO to only conduct IGA and submit audit report. The organization prioritizes the measures for implementation based on time, capital investment and payback period.

A detailed audit includes data collection, measurements of the systems, analysis of the historical and measured data, and detailed energy savings calculations for suggested projects. The ESCO not only analyzes the performance of individual equipment, but evaluates the complete system in order to obtain a comprehensive efficiency solution that captures all energy efficiency opportunities, not just the more obvious ones.

An investment grade evaluation includes the following:

- Description of the baseline situation
- Project design, including basic engineering

- Technical analysis
- Project financials
- Baseline calculation
- Options for monitoring and verification
- Assessment of potential technical and financial risk and a risk mitigation plan

Based on IGA and discussions with organization, list of potential projects are prepared for implementation. The approved projects are taken up for detailed financial analysis taking into account savings, costs for engineering, design and implementation If the project is financed by commercial bank, detailed cash flow, internal rate of return, debt service coverage ratio and sensitivity analysis are prepared.

g) Risk assessment and mitigation plan is prepared covering design and construction risk, performance risk, financial, economic and regulatory risk.

h) Monitoring and verification of the project progress as per agreed protocols by organization and ESCO to undertake any midcourse correction for successful implementation.

Calculating savings

In addition to agreeing upon the baseline and allowable adjustments, both organisation and the ESCOs must agree on how to calculate the energy and cost savings resulting from the project. Once the work has been done to determine the baseline and adjustments, the energy savings is calculated as:

Energy Saved = Baseline – Current +/- Adjustment

Where,

Energy saved is the energy saved over a period of time from project start to a set point in time

Baseline is the baseline energy consumption (say in kWh)

Current is the current energy consumption (determined by metering or the utility energy bill)

Adjustments are any adjustments, positive or negative, that need to be made to the baseline to bring energy use at the current point in time to the same set of conditions as the baseline set.

In order to calculate cost savings from the energy savings, the parties must agree on how to handle energy price fluctuations because the resulting amount should be a function only of the efficiency measures, not fluctuating energy costs. One method is to agree on a set price, either one defined upfront in the performance contract, or a formula or definition for calculating one (e.g. the average monthly energy cost over the time period being examined). These are details that need to be negotiated in the performance contract.

7.9 A Case Study - Energy Efficiency in Buildings through ESCO

Project

ABC is one of buildings taken up for implementation of Energy Efficiency Measures (EEMs) under performance contracting. The investment grade energy audit for both buildings was conducted and

energy savings potential was estimated. During the energy audit, special consideration was given to the application of performance measurement and verification system. The energy audit included collection of past energy consumption data and field-testing of various energy consuming equipment and systems.

Summary of EEMs

The energy efficiency measures are developed based on individual energy systems. The major energy consumption in the ABC Tower is in Lighting and Air Conditioning systems. A brief overview of EEMs is presented in table 7.1 below:

Table 7.1 Overview of Energy Efficiency Measures

S.No.	Area	Brief Description
1.	Lighting	Retrofit based on Design and Technology for task lighting
2.	Air Conditioning	Replacement of Window and Split ACs with Centrifugal Chiller based Central AC System
3.	Winter Heating	With the infrastructure available for central cooling distribution system, it is possible to use the same for Central Heating System in winter at marginal cost
4.	Pumping System	Replacement of existing pumps with the more efficient pumps and piping modification for more efficient pumping
5.	Canteen Heating	Replacing Electrical heating with LPG heating

In addition to the capital cost for EEMs mentioned above, additional costs will be incurred for baseline establishment, detailed engineering of EEMs and preparation of Detailed Project Report (DPR) in project preparation.

The total energy reduction potential is estimated to be 39% in energy consumption and 33% in energy bill.

Summary of Project Financials

The project financials indicate viability if all the EEMs are implemented together. The project assumes the ownership of all EEM assets with contractor and at the end of the contract it is transferred to the facility owner at nominal costs. The project viability is further improved as the contractor is given the responsibility of disposing the existing assets, which are being replaced by the more efficient one, and contractor is given the benefit.

Performance Measurement and Verification (PMV)

Contractor and facility owner shall do the performance measurement and verification jointly. The PMV would ensure that the guaranteed savings have been achieved. The whole facility PMV has been selected for establishing baseline and post implementation verification. This baseline is established

based on the historical energy bills, inventory, weather data and adjustments. After the implementation of project, the actual savings is calculated based on the facility utility bills after making adjustments.

Operation and Maintenance

The Contractor's payments are linked to the actual energy bill reduction during the contract period. To ensure the savings, Contractor shall also do the operation and maintenance of the building energy system during the contract period.

Baseline Power Consumption

The present power consumption based on the analysis of three years energy bill and adjusting the errors in the metering is as follows.

Baseline Energy Consumption

Sl.No.	Month	Baseline Energy Consumption, kWh
1	January	165390
2	February	127480
3	March	120570
4	April	214800
5	May	216090
6	June	245320
7	July	253742
8	August	231330
9	September	176477
10	October	152870
11	November	104506
12	December	119970
13	**Complete One Year**	**2128545**

Savings Guarantees

The contractor guarantees that in each year of the term following substantial completion, the facility owner will realize the savings of at least 7,93,250 kWh (95% of the proposed 39% savings of approximately 8,35,000 kWh)

Term of Contract

The term of the Performance Contract and Maintenance services is 5 years from the day of Project.

Energy Saving Payments

The energy savings would be shared between contractor and facility owner in the ratio of 95% for contractor and 5% for owner for the first three years and in the ratio of 90% for contractor and 10% for owner in the fourth and fifth year. From the sixth year, the asset would be transferred to the host at the end of the contract period at nominal cost.

Maintenance Expenses Payment

In addition to above facility owner will pay contractor a fixed sum for maintaining the Energy Efficiency Measures.

7.10 Municipal Energy Efficiency Project through Performance Contracting

Project selection basis:

Municipalities spend large amounts of its money on purchasing energy for public services such as street lighting and water supply. Energy saving potential in water pumping alone is estimated at least 25 percent.

The budgets for these services lack funds to invest in energy efficiency improvements, and municipalities are looking for alternative ways to finance energy efficiency projects. Performance contracting is one such alternative to finance efficiency improvement projects without upfront investment. The project cost is paid out of the savings accrued thus allowing municipalities to finance the improvements out of savings accrued from the project.

In municipalities, performance contracts may often involve engineering firms such as water engineering companies in case of efficiency project involving water supply, other than an ESCO. However, ESCO participation in the project is beneficial because they bring managerial, technical and turn-key project implementation skills that often are lacking at the municipalities combined with the ability to structure project financing. Based on the municipalities' needs, the ESCOs can finance EE implementation and collect their dues from shared or guaranteed savings accruing from the EE project.

Steps for developing Energy Efficiency Project in Municipality

1. Identify reasons for undertaking EE project. If need for EE project is established as a priority. Municipality should select most suited contract and financing option
2. Collect energy usage data by carrying out a preliminary (walk-through) audit. Municipalities should collect basic data on energy usage in an information sheet and internally assess the low cost and no cost options that can be implemented using its own operation and maintenance (O&M) funds **(Self-assessment)**.
3. Develop and issue a request for Expressions of Interest (EOI) for conducting an investment grade energy audit and implementing an efficiency project in the target sector(s), such as water, wastewater, street lighting and municipal buildings. The EOI contains a brief description of the scope of work and basic information on the municipal installations to be audited, and requests information on the technical and financial capabilities of service firms including their personnel, audit instrumentation, and relevant experience.
4. Issue a Request for Proposal (RFP) to all viable firms who submitted EOIs. The RFP describes the facility's energy use, equipment, operating schedule, maintenance problems, and equipment

replacement or renovation plans, as well as the utility bill history for the past three years. It is desirable that a site visit be organized for interested ESCOs to tour the facility and interview facility staff before submitting their responses to the RFP.

5. Evaluate the proposals according to the terms of the RFP.
6. Finalize ESCO selection based on its expertise and relevant experience, making sure to match the skills of the ESCO with the needs of the Municipality.
7. Award the Investment Grade Audit (IGA) contract, which is an agreement with the ESCO to develop a project concept, and perform the IGA. The IGA report forms the basis for the energy performance contract between the Municipality and ESCO, identifying all feasible short-medium- and long-term energy saving measures and their payback periods, and providing the baseline data to be used during monitoring and verification.
8. Package the documentation for third party financing, if necessary. The party taking on the financing (be it the Municipality or ESCO) puts together a package of information on the project, including the IGA report, for review by financial institutions. The financially relevant information contained in the IGA report is critical at this stage for convincing a financial institution to provide a loan.
9. Enter into the performance contract. The contract sets the terms and conditions, by which the ESCO implements the energy efficiency measures, including the responsibilities of the ESCO and Municipality, the compensation schedule for the ESCO, financing conditions, maintenance, personnel training, monitoring and verification procedures, risks and a risk mitigation plan, and the definition of the baseline and possible adjustments to it.
10. Monitoring and Verification (M&V) of results is performed according to the procedures in the performance contract. M&V determines the actual savings over the period of the contract and ensures that all parties are getting full value from the energy performance contract, including compensation for the ESCO. It includes approval of equipment installation based on the contract specifications, and involves regular communication between the ESCO and Municipality to monitor successful implementation of the energy saving measures. Often, M&V can be performed by an independent third party expert(s).

Solved Example:

An oil fired reheating furnace heats steel billets from 40^{o}C to 1220^{o}C at a furnace efficiency of 28%. The furnace operates for 4700 hours per annum. The GCV of furnace oil is10,000 kcal /kg and density is 0.94kg/litre. The cost of furnace oil is Rs.45 /liter. The specific heat of billets is 0.12 kcal/kg^{o}C.

a. Calculate the amount of energy necessary to heat 12 tons of steel billets per hour
b. Calculate liters of furnace oil fired per tons of steel billets.
c. If the efficiency of the furnace is improved from 28% to 30% by adopting ceramic fibre insulation, calculate the hourly furnace oil cost saving

d. What is the simple payback period if the investment is Rs. 20 lakhs ?

e. How large could be the investment to improve the efficiency at an internal rate of 16% and per year over 6 years.

Ans:

a) Amount of energy necessary to heat 12 tons of steel billets

= m x cp x t

= 12000 Kgs x 0.12 x (1220- 40) kcals/hr

= 16,99,200 kcals/hr

b) Litres of furnace oil fired per ton of steel billet

= [(1699200/12)]

= 141600 Kcal/ tonne of billet

Input energy per ton of billet = 141160/0.28

= 505714 kcal/ tonne of billet

Furnace oil required in kg = $\frac{505714}{10,000}$

= 50.57 Kg/ tonne of billet

Furnace oil required in litres = $\frac{50.57}{0.94}$

= 53.79 litres/ tonne of billet

c) Hourly furnace oil cost savings/ton

= 53.79 x [1 – (0.28/0.30)] * Rs 45

= Rs 161.37/tonne

Hourly furnace oil cost savings for 12 tons

= Rs 161.37 *12

= Rs 1936/hr

d) Simple payback period @ 4700 hrs of operation

= 20,00,000/1936*4700

= 0.352 yrs or 4.2 months

e) Net cash inflow per annum = 1936*4700

= Rs 91.0 lakhs

$$\text{Investment} = 91.0 \left[\frac{1}{1.16} + \frac{1}{(1.16)^2} + \frac{1}{(1.16)^3} + \frac{1}{(1.16)^4} + \frac{1}{(1.16)^5} + \frac{1}{(1.16)^6} \right]$$

= 91.0 [0.862+ 0.743+0.641+0.552+0.476+0.410]

= Rs. 3.35 Crores

QUESTIONS

Objective Type Questions

1.	What does the concept of time value of money imply a) present value of money b) future value of money c) discounting of cash flows d) all of the above
2.	Return on Investment (ROI) as a fraction means a) initial investment / annual return b) annual cost / cost of capital c) annual net cash flow / capital cost d) none of the above.
3.	The net present value (NPV) is a) equal to the sum of the present values of all cash flows b) equal to the sum of returns c) equal to the sum of all cash flows d) none of the above
4.	The Internal Rate of Return (IRR), of an investment is calculated by a) selecting a discount rate so that NPV = 0 b) equating total discounted costs with total discounted benefits c) making sure the benefit / cost ratio equals unity d) all of the above
5.	Assume project A has an IRR of 85% and NPV of Rs 15,000 and project B has an IRR of 25% and NPV of 200,000. Which project would you implement first if financing is available and project technical life is the same? a) B b) A c) cannot be decided d) question does not make sense
6.	Which of the following equation can be used to calculate the future value from the present value of cash? a) NPV = FV x $(1 + i)^n$ b) FV= NPV x $(1 - i)^n$ c) NPV =FV/ $(1 + i)^n$ d) none of the above.
7.	The Net Present Value of a project at a discount rate of 16% with an investment of Rs 50,000 at the beginning of the first year, and savings of Rs 23,000 and Rs 36,000 at the end of the first and second year, respectively is a) 6,581 b) -246 c) 862 d) 3,419
8.	A sum of Rs 10,000 is deposited in a bank at the beginning of a year. The bank pays 6% interest annually. How much money is in the bank account at the end of the fifth year, if no money is withdrawn? a) 13,382 b) 12,625 c) 13,000 d) 10,937
9.	The broad indicator of the annual return expected from initial capital investment is a) NPV b) IRR c) ROI d) Discount factor
10.	Which among the following is not a typical performance contract a) Shared savings b) Guaranteed savings c) Fixed fee d) Hire purchase

<table>
<tr><th colspan="2">Short Type Questions</th></tr>
<tr><td>S-1</td><td>100 numbers of fused 60 Watt incandescent light bulbs (ILB) are replaced by same numbers of 12 Watt CFL instead of new ILB. Calculate the following for 4000 hours of operation per year.

(i) The annual reduction in electricity costs if Rs. 4 per kWh is the energy charge and Rs. 250 per kVA per month is the demand charge.

(ii) The simple payback period if the ILB costs Rs. 10 and the CFL costs Rs. 100 (assume life of ILB and CFL as 1000 hours and 4000 hours respectively).</td></tr>
<tr><td>S-2</td><td>Explain briefly the operation of an ESCO?</td></tr>
<tr><td>S-3</td><td>What are the limitations of payback period?</td></tr>
<tr><td>S-4</td><td>What are the limitations of ROI method?</td></tr>
<tr><td>S-5</td><td>Compare between NPV and IRR?</td></tr>
<tr><th colspan="2">Long Type Questions</th></tr>
<tr><td>L-1</td><td>A company invests Rs.10 lakhs and completes an energy efficiency project at the beginning of year 1. The firm is investing its own money and expects an internal rate of return, IRR, of at least 26% on constant positive annual net cash flow of Rs.2 lakhs, over a period of 10 years, starting with year 1.

1. Will the project meet the firm's expectations?
2. What is the IRR of this measure?</td></tr>
<tr><td>L-2</td><td>The cost and estimated savings data for an energy saving retrofit project is given in table below.

<table>
<tr><th>Retrofit cost</th><th>Energy & demand savings</th><th>Maintenance cost savings</th></tr>
<tr><td>Rs. 1,00,000</td><td>6000 kWh/year & Rs.3800/ year as demand charges</td><td>Annual maintenance cost savings will be Rs. 2000/-.</td></tr>
</table>

The key data is given below:
Energy savings are based on Rs 3.00/kWh
No changes in energy rates for 10 years
The project has a 10 year life period

Calculate NPV for the upgrade option against 12% discount rate.</td></tr>
</table>

REFERENCES

1. Financial Management, Tata Mc-Graw Hill – Prasanna Chandra.
2. Manual for the Development of Energy Efficiency Project ----International Finance Corporation.

Chapter 8

Project Management

Learning Objectives

In this chapter you will learn about

- Principles of project planning relevant to energy management
- Elements of project management
- Financing options for implementing energy management projects
- Project planning and monitoring techniques

8. PROJECT MANAGEMENT

Definition and scope of project, Technical design, Financing, Contracting, Implementation and performance monitoring, Implementation plan for top management, Planning Budget, Procurement procedures, Construction, Measurement and verification.

8.1 What is a Project?

A project is a "temporary endeavor undertaken to create a unique product or service".

Projects are temporary because they have a definite beginning and a definite end. They are unique because the product or service they create is different in some distinguishing way from similar products or services.

Designing, installation and commissioning of a cogeneration system in an industry is an example of a project. The unique work is defined by the cogeneration system and has a specific beginning and end. A project manager is responsible for the project, overseeing the contractors and managing the schedule and budget.

Projects are means for change. Such change can be sought or it can be resisted. Changing practices or investing money for energy efficiency is an occurrence of change. Fortunately, energy related projects generally have low risk attached to both the means of achieving change and result of that change.

The energy manager should seek opportunities to save energy and aim to influence all projects in which energy is a significant factor. It may be that, in the early stages, an energy benefit will add to the arguments in favour of the project. Investment in energy efficiency is also good publicity news that can be given to customers and media.

Project management is a set of principles, methods, and techniques that people use to effectively plan and control project work. Project management principles and techniques help complete projects on schedule, within budget, and in full conformance to project specifications. At the same time, they help achieve the other goals of the organization, such as productivity, quality, and cost effectiveness.

The objective of project management is to optimize project cost, time, and quality.

8.2 Project Development Cycle (PDC)

The various steps in the PDC are:

1. Project Identification and Screening
2. Technical Design
3. Financing
4. Contracting
5. Implementation
6. Performance Monitoring

Project Identification and Screening

The first step in the project development cycle is to identify components of the project. Projects may be identified both internally and externally:

- Internal identification takes place when the facility manger identifies a package of energy saving opportunities during the day-to-day energy management activities, or from detailed energy audits.
- External identification of energy savings can occur through systematic energy audits undertaken by a reputable energy management consultant, energy service company or industry organization.

In screening projects, the following criteria should be used to rank project opportunities:

- Economic feasibility of energy savings measures (Internal rate of return, net present value, cash flow, average payback)
- Sustainability of the savings over the life of the equipment.
- Ease of quantifying, monitoring, and verifying energy savings.
- Availability of technology, and ease of adaptability of the technology to Indian conditions.
- Other environmental and social cost benefits (such as reduction in GHG emissions and local pollutants such as SO_x emissions)

Technical Design

For a project to be considered a viable investment, the project proponent must present a sound technical feasibility study that identifies the following elements in detail:

- ❖ The proposed new technologies, process modifications, equipment replacements and other measures included in the project.
- ❖ Product/technology/material supply chain (e.g., locally available, imported, reliability of supply)
- ❖ Any special technical difficulties (installation, maintenance, repair), associated skills required.
- ❖ Preliminary designs, including schematics, for all major equipment needed, along with design requirements, manufacturer's name and contact details, and capital cost estimate.
- ❖ Organizational and management plan for implementation, including timetable, personnel requirements, staff training, project engineering, and other logistical issues.

Financing

When considering a new project, it should be remembered that other departments in the organization would be competing for capital for their projects. However, it is also important to realize that energy efficiency is a major consideration in all types of projects, whether they are:

- Projects designed to improve energy efficiency
- Projects where energy efficiency is not the main objective, but still plays a vital role.

Most organization reaches the point when all the obvious measures to save energy have been taken and capital investment is needed to make further savings. Low cost measures for saving energy, which can be treated as mini projects in their own rights, should be given top priority. It is necessary to ensure that the present system is operating efficiently before spending any money.

If all the projects in a portfolio of applications to top management are within the policy and the procedures of the organization, then the one chosen for approval is likely to be the one, which gives the best return on the investment, and which is best presented. Many organizations have a priority list which gives preference to capital expenditure on projects offering certain advantages or removing particular disadvantages.

Project funds can be obtained from either internal or external sources.

Internal sources include:

- Direct cash provision from company reserves
- Revenue budget (if payback is less than one year)
- New share capital

External sources of funds include:

- Bank loans
- Leasing arrangement
- Payment by savings i.e. a deal arranged with equipment supplier
- Energy services contract
- Private finance initiative

Before applying for project fund, all the options for funding the project are discussed with finance managers. Often, energy savings improve viability of non-energy projects.

The availability of external funds depends on the nature of your organization. The finance charges on the money borrowed will have an impact on the validity of the project.

If outside financing is sought for an energy management project, it may be obtained from a private bank, or from one of the special financing programs offered by national development banks and other funding agencies. In addition to the usual information on company assets and lines of credit, financial agencies will require an assessment of the financial feasibility of the proposed project. This should include a fully specified *pro forma* financial worksheet that presents project cash flows, net present value, and internal rate of return.

Contracting

Since a substantial portion of a project is typically executed through contracts, the proper management of contracts is critical to the successful implementation of the project. In this context, the following should be taken care.

- The competence and capability of all the contractors must be ensured-one weak link can affect the timely performance of the contract.

- Proper discipline must be inculcated among contractors and suppliers by insisting that they should develop realistic and detailed resource and time plans that are matching with the project plan.
- Penalties-which may be graduated-must be imposed for failure to meet contractual obligations. Likewise, incentives may be offered for good performance.
- Help should be extended to contractors and suppliers when they have genuine problems-they should be regarded as partners in a common pursuit.
- Project authorities must retain independence to off-load contracts (partially or wholly) to other parties well in time where delays are anticipated.

If the project is to be implemented by an outside contractor, several types of contract may be used to undertake the installation and commissioning:

- **Traditional Contract**: All project specifications are provided to a contractor who buys and installs equipment at fixed price or cost plus a mark-up. Also called as fixed-price or lump sum contract, the contractor takes the risk of unforeseen problems in exchange for a larger profit. This type of contract is appropriate when dealing with unknown vendors or when project manager anticipates the work is risky.
- **Extended Technical Guarantee/Service**: The contract offers extended guarantees on the performance of selected equipment, and/or offers service/maintenance agreements.
- **Extended Financing Terms**: The contractor provides the option of an extended lease or other financing vehicle in which the payment schedule can be based on the expected savings.
- **Guaranteed Saving Performance Contract**: All or part of savings is guaranteed by the contractor, and all or part of the costs of equipment and/or services is paid down out of savings as they are achieved.
- **Shared Savings Performance Contract**: The contractor provides the financing and is paid an agreed fraction of actual savings as they are achieved. This payment is used to pay down the debt costs of equipment and/or services.

Implementation

A great deal of the emphasis in the planning stage of any project is on understanding where and when problems may occur. Many projects introduced by energy managers end up as some other manager's responsibility, e.g. a production manager or a works engineer. The following needs to be thought ahead and anticipated.

- Type and extent of measurements needed to control and measure the success of the project
- Winning the confidence and cooperation of key personnel involved.
- Timely and frequent communication between participants.

With proper techniques, changes and modifications in project can be understood and incorporated without loss of control.

Before considering the components of a plan, its purpose must be defined. A plan turns a proposed project into reality. As reality often differs from theory, the plan should consider as many technical, financial and other 'what ifs' as possible.

Performance Monitoring

In order to keep a tab on the progress of the project, a system of monitoring must be established. This helps in:

- Anticipating deviations from the implementation plan
- Analyzing emerging problems
- Taking corrective action

In developing a system of monitoring, the following points must be borne in mind:

- It should focus sharply on the critical aspects of project implementation.
- It must lay more emphasis on physical milestones and not on financial targets.
- Monitoring must be kept simple.

Project Review

Once the project is commissioned the review phase has to be set in motion. Performance review should be done periodically to compare actual performance with projected performance. A feedback device, it is useful in several ways:

a) It throws light on how realistic were the assumptions underlying the project
b) It provides a documented log of experience that is highly valuable in future decision making
c) It suggests corrective action to be taken in the light of actual performance
d) It helps in uncovering judgmental biases

8.3 Project Planning Techniques

To achieve control of a project, it is necessary to plan. For more complex projects, the more advanced planning methods are needed. Many project management software packages are available with detailed operational manuals.

Work Breakdown Structure (WBS)

Work Breakdown Structure (WBS) is the process of dividing complex projects to simpler and manageable tasks. The project managers use this method for simplifying the project execution. In WBS, much larger tasks are broken down to manageable chunks of work. These chunks can be easily supervised and estimated.

First main deliverable of a project is identified and then the higher levels tasks are broken into smaller chunks of work. In the process of breaking down the tasks, one can break them down into different levels of detail. The level of breakdown detail depends upon project type and the management style followed for the project. WBS can be displayed using tree structure or list or tables.

WBS is developed before dependencies are identified and activity durations are estimated. The WBS can be used to identify the tasks before constructing Gantt chart and networks such as Critical Path Method -CPM and Program Evaluation and Review Technique- PERT.

Gantt chart

During the era of scientific management, Henry Gantt developed a tool for displaying the progress of a project in the form of a specialized chart. An early application was the tracking of the progress of ship building projects. Today, Gantt's scheduling tool takes the form of a horizontal bar graph and is known as a **Gantt chart.**

Gantt chart is now commonly used for scheduling the tasks and tracking the progress of energy management projects. Gantt charts are developed using bars to represent each task. The length of the bar shows how long the task is expected to take to complete. The duration is easily shown on Gantt charts.

A basic sample for a pumping station is shown in Figure 8.1. The horizontal axis of the Gantt chart is a time scale, expressed either in absolute time or in relative time referenced to the beginning of the project. The time resolution depends on the project - the time unit typically is in weeks or months. Rows of bars in the chart show the beginning and ending dates of the individual tasks in the project.

ID	Task Name
1	Start
2	Mobilize
3	Survey
4	Grade site
5	Trench footings
6	Form and pour concrete
7	Cure concrete
8	Concrete and material design
9	Spec prefab metal building
10	Plumbing materials, pump, etc.
11	Electrical materials, lights, panel
12	Install pump
13	Erect structural steel
14	Install roofing and siding
15	Install lights and panels
16	Test pump
17	Paint
18	End

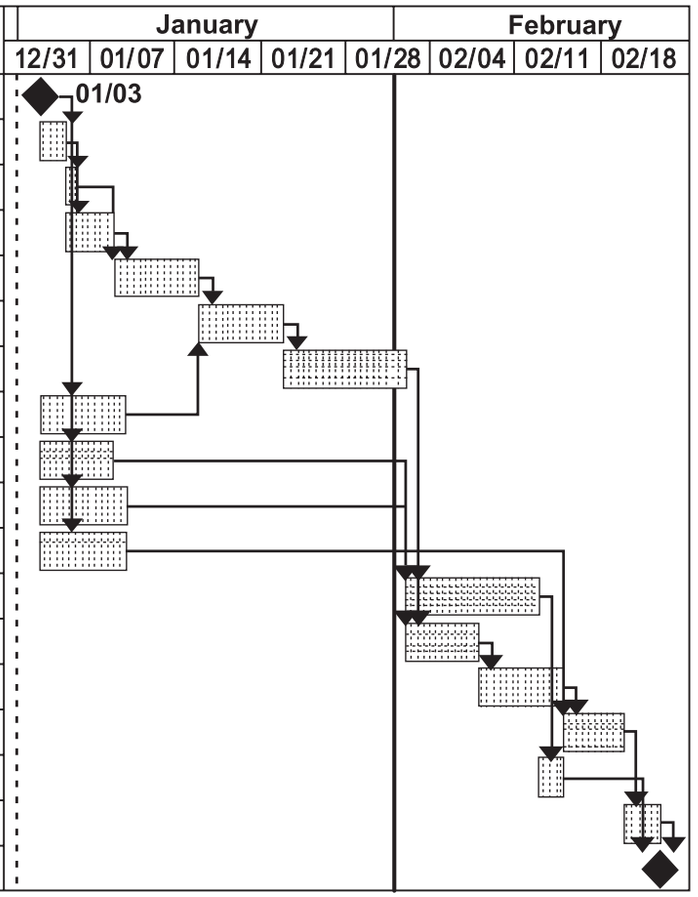


Figure 8.1 Gantt Chart for a Pumping Station

In the example in Figure 8.1, each task is shown to begin when the task preceding it completes. However, the bars may overlap in cases where a task can begin before the completion of another, and there may be several tasks performed in parallel. For such cases, the Gantt chart is quite useful for communicating the timing of the various tasks.

Limitation of Gantt chart

The Gantt chart does not normally show the logical interdependencies between the predecessor and successor activities very well. Such requirements are best served by the network diagram, which shows logic clearly but does not have a time scale axis like the Gantt chart.

Gantt Chart Enhancement

This basic version of the Gantt chart often is enhanced to communicate more information.

- A vertical marker can used to mark the present point in time (If a vertical line is drawn through a given day, the activities that are scheduled to be taking place simultaneously will have the line pass through them. In this way the need for simultaneous resources can clearly be seen).
- The progression of each activity may be shown by shading the bar as progress is made, allowing the status of each activity to be known with just a glance.
- Dependencies can be depicted using link lines or color codes.
- Resource allocation can be specified for each task.
- Milestones can be shown.

Project Networking Techniques

Project network shows dependency relationships between tasks/activities in a project in a graphical view. It shows clearly tasks that must precede or succeed other tasks in a logical manner. It is a powerful tool for planning and controlling project

Network Definitions

Activity: Any portions of project (tasks) which required by project, uses up resource and consumes time.

Event: Beginning or ending points of one or more activities are called ‘nodes’

Network: Combination of all project activities and the events

Two ways of representing activities are *activity-on-arrow (AOA)* and *activity-on-node (AON)*.

Activity-on-arrow (AOA) is represented by the activities on arrows which are connected at events (nodes shown as circles) to show the dependencies (preceding or succeeding) as shown in Figure 8.2.

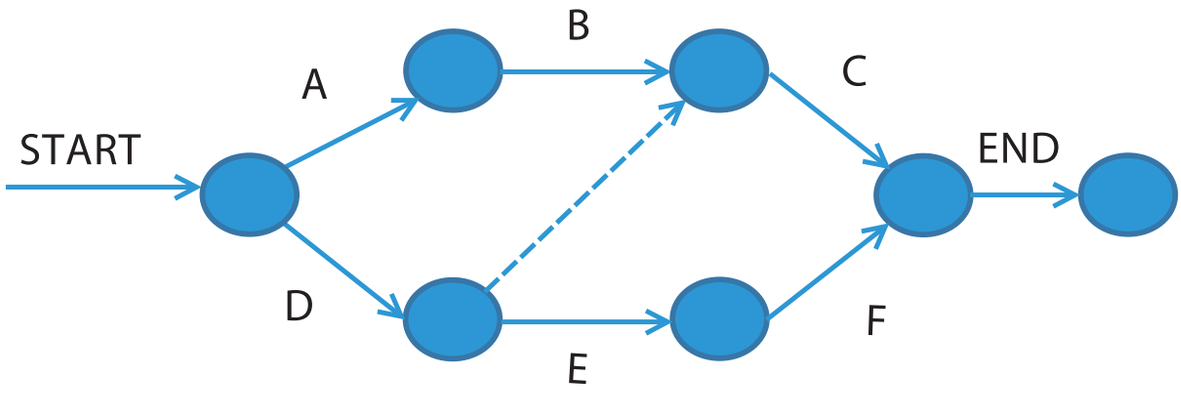


Figure 8.2 Activity-On-Arrow Method

Activity-on-node (AON) is represented as nodes on the network and events that signify the beginning or ending of activities are depicted as arcs or lines between the nodes as shown in Figure 8.3. This method is used in project management software packages.

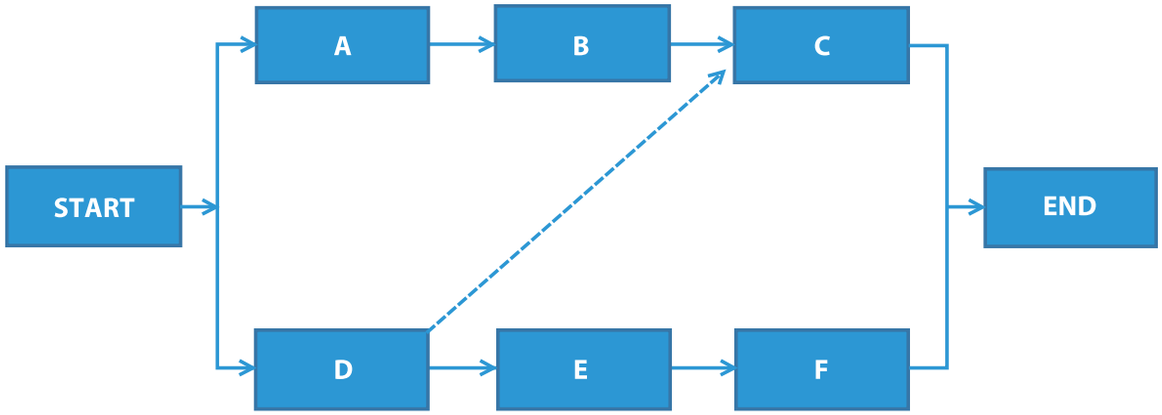


Figure 8.3 Activity-On-Node Method

Dummy activity is required if two or more activities having identical starting and ending events. In above Figures, it is shown as dotted line to ensure that activity C starts only after activity B and activity D are completed.

Critical Path Method (CPM)

In 1957, DuPont developed a project management method designed to address the challenge of shutting down chemical plants for maintenance and then restarting the plants once the maintenance had been completed. Given the complexity of the process, they developed the **Critical Path Method** (CPM) for managing such projects.

CPM provides the following benefits:

- Provides a graphical view of the project.
- Predicts the time required to complete the project.
- Shows which activities are critical to maintaining the schedule and which are not.

Steps in CPM Project Planning

1. Specify the individual activities.
2. Determine the sequence of those activities.
3. Draw a network diagram.
4. Estimate the completion time for each activity.
5. Identify the critical path (longest path through the network)
6. Update the CPM diagram as the project progresses.

1. Specify the Individual Activities

From the work breakdown structure, list the activities in the project. The project (made up of several tasks) should have only a single start activity and a single finish activity.

2. Determine the Sequence of the Activities

Develop the relationship among the activities. Decide which activities must precede and which must follow others.

3. Draw the Network Diagram

Draw the "Network" once all the activities and their sequencing have been defined. Network diagram originally was developed as an *activity on node* (AON) network, but some project planners prefer to specify the *activities on the arrow*.

4. Estimate Activity Completion Time

Assign time and/or cost estimates to each activity using past experience or the estimates of knowledgeable persons.

CPM is a ***deterministic model*** that does not take into account variation in the completion time, so one fixed time is used for an activity.

5. Identify the Critical Path

The critical path is the longest-duration path through the network. The significance of the critical path is that the activities that lie on it cannot be delayed without delaying the project. Because of its impact on the entire project, critical path analysis is an important aspect of project planning.

The critical path can be identified by determining the following four parameters for each activity:

- ES - Earliest start time: the earliest time at which the activity can start given that its precedent activities must be completed first.
- EF - Earliest finish time: equal to the earliest start time for the activity plus the time required to complete the activity.
- LF - Latest finish time: the latest time at which the activity can be completed without delaying the project.
- LS - Latest start time, equal to the latest finish time minus the time required to complete the activity.

The total float (*slack time)* for an activity is the time between its earliest and latest start time, or between its earliest and latest finish time. Slack is the amount of time that an activity can be delayed past its earliest start or earliest finish without delaying the project.

The critical path is the path through the project network in which none of the activities have slack, that is, the path for which ES=LS and EF=LF for all activities in the path. A delay in the critical path delays the project. Similarly, to accelerate the project it is necessary to reduce the total time required for the activities in the critical path.

6. Update CPM Diagram

As the project progresses, the actual task completion times will be known and the network diagram can be updated to include this information. A new critical path may emerge, and structural changes may be made in the network if project requirements change.

Example 8.1: Illustration of CPM

WBS of a project is given in Table 8.2.

Table 8.2 WBS for a Project

Activity	Immediate Predecessor	Completion Time (weeks)
A	-	5
B	-	6
C	A	4
D	A	3
E	A	1
F	E	4
G	D,F	14
H	B,C	12
I	G,H	2

The information in WBS indicates that the total time required to complete activities is 51 weeks. However, it can be seen from the network that several of the activities can be conducted simultaneously (A and B, for example). It is necessary to calculate critical path of the network.

Earliest Start Time and Earliest Finish Time

We can do a forward pass calculations. Starting at the network's origin (node 1) and using a starting time of 0, we compute an ***earliest start (ES)*** and ***earliest finish (EF)*** time for each activity in the network. The expression EF = ES + t can be used to find the earliest finish time for a given activity. The completion time or the duration of an activity is represented as t.

For example, for activity A, ES = 0 and t = 5; thus the earliest finish time for activity A is EF = 0 + 5 = 5. Refer Figure 8.4.

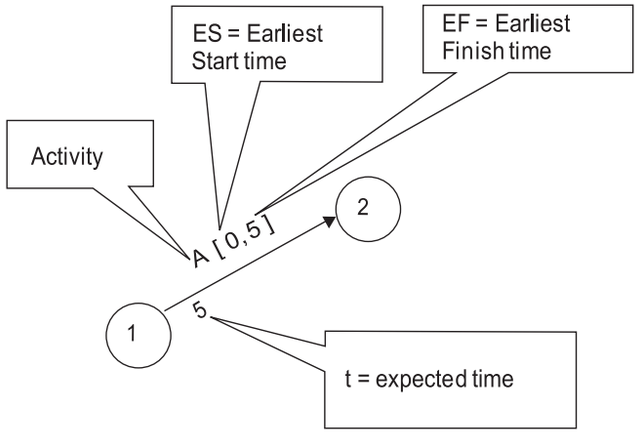


Figure 8.4 Early Start Time and Early Finish Time

Completing the network from start based on above (Forward pass), we can calculate all ES and EF time as shown in Figure 8.5.

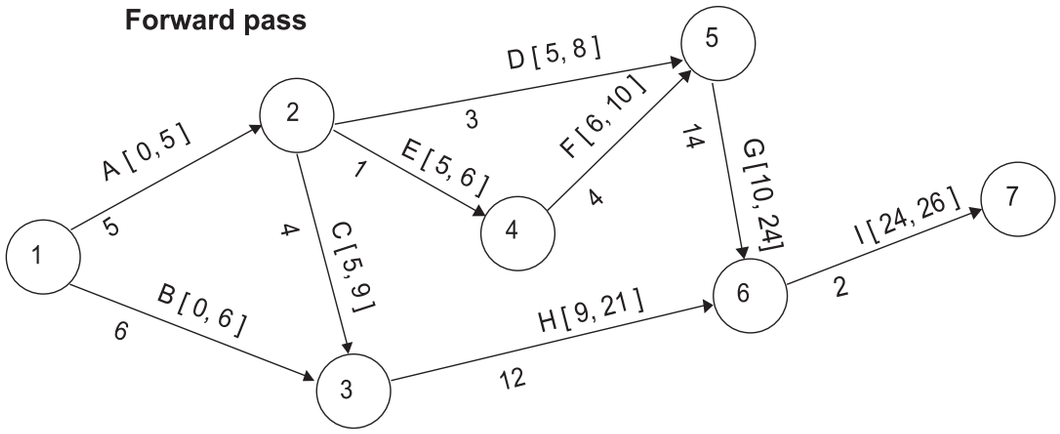


Figure 8.5 Network with ES and EF time in Forward Pass

Earliest start time rule:

The earliest start time for an activity leaving a particular node is equal to the **largest** of the earliest finish times for all activities entering the node.

Similarly, we can do a backward pass calculation. Starting at the completion point (node 7) and using a ***latest finish*** time (LF) of 26 for activity I, we trace back through the network computing a ***latest start*** (LS) and latest finish time for each activity

The expression **LS = LF – t** can be used to calculate latest start time for each activity. For example, for activity I, LF = 26 and t = 2, thus the latest start time for activity I is LS = 26 – 2 = 24.

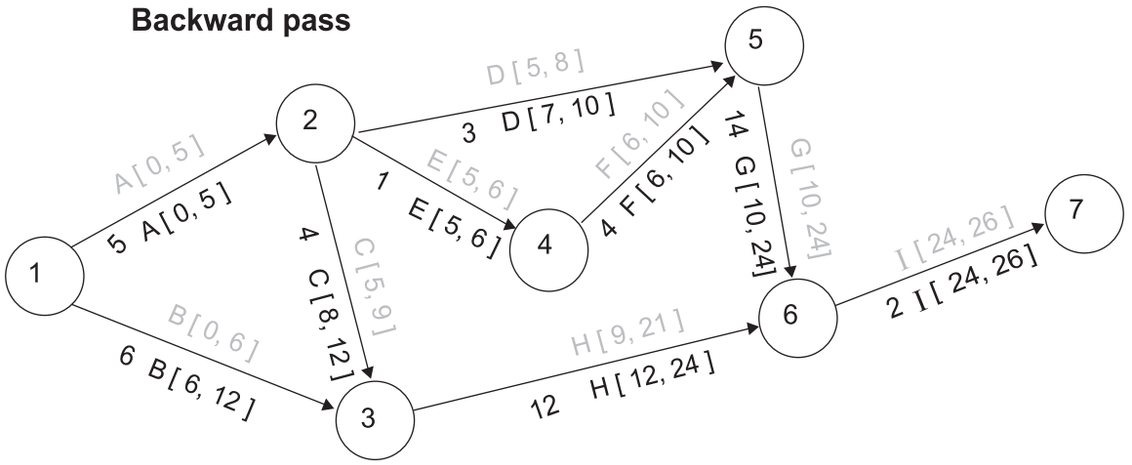


Figure 8.6 Network with LS and LF time in Backward Pass

Latest finish time rule:

The latest finish time for an activity entering a particular node is equal to the **smallest** of the latest start times for all activities leaving the node.

Float or Slack or Free Time

Slack is the length of time an activity can be delayed without affecting the completion date for the entire project. For example, slack for C = 3 weeks, i.e Activity C can be delayed up to 3 weeks {LS (8 weeks) – ES (5 weeks) or LF (12 weeks) – EF (9 weeks) = 3 weeks} as given in Figure 8.6.

Float or slack shows how much allowance each activity has i.e. how long it can be delayed without affecting the completion date of the project. Critical path is a sequence of activities from start to finish with zero slack. Critical activities are activities on the critical path.

Critical path identifies the minimum time to complete project. If any activity on the critical path is shortened or extended, project time will be shortened or extended accordingly. If resources have to be

spent to speed up some activities, it should be only for critical activities. Such shortening or project in critical path by adding resources is called project crashing. If resources have to be saved by lengthening some activities, it should be only for non-critical activities, up to the limit of float.

Table 8.3 Summary of Project Calculations

Activity	Duration (weeks)	Earliest Start ES	Earliest Finish EF	Latest Start LS	Latest Finish LF	Float or Slack LS-ES or LF-EF	Critical Path
A	**5**	**0**	**5**	**0**	**5**	**0**	**Yes**
B	6	0	6	6	12	6	
C	4	5	9	8	12	3	
D	3	5	8	7	10	2	
E	**1**	**5**	**6**	**5**	**6**	**0**	**Yes**
F	**4**	**6**	**10**	**6**	**10**	**0**	**Yes**
G	**14**	**10**	**24**	**10**	**24**	**0**	**Yes**
H	12	9	21	12	24	3	
I	**2**	**24**	**26**	**24**	**26**	**0**	**Yes**

The total time to complete the activities is 26 weeks. The activities which are critical and must be completed to keep the project within schedule are A, E, F, G, and I. Non-critical activities can be delayed before they cause delay in project completion time as per float or slack shown against each activity shown in Table 8.3.

Program Evaluation and Review Technique (PERT)

The *Program Evaluation and Review Technique* (PERT) is a ***probabilistic*** network model that allows for randomness in activity completion times. PERT was developed in the late 1950's for the U.S. Navy's Polaris project having thousands of contractors. It has the potential to reduce both the time and cost required to complete a project.

PERT steps are similar to CPM with only difference as to the estimation of time. Unlike CPM where times can be estimated with relative certainty, confidence, PERT uses 3 time estimates.

$\boldsymbol{T_m}$ **= most likely time estimate**

T_o **= optimistic time estimate**

$\boldsymbol{T_p}$ **= pessimistic time estimate**

PERT assumes a normal bell-shaped distribution (beta probability distribution) for the time estimates. For a beta distribution, the expected time for each activity can be approximated using the following weighted average:

Expected time = (Optimistic + 4 x Most likely + Pessimistic) / 6

Expected Time (T_e) = ($T_o + 4T_m + T_p$) /6

Standard Deviation (σ) = ($T_p - T_o$) / 6

Variance (V) = { ($T_p - T_o$) / 6 }^{2}

The variance in the project completion time can be calculated by summing the variances in the completion times of the activities in the critical path. Given this variance, one can calculate the probability that the project will be completed by a certain date assuming a normal probability distribution for the critical path. The normal distribution assumption holds if the number of activities in the path is large enough.

The calculation procedure is similar to CPM. The expected times may be displayed on the network diagram. The various times are calculated using the expected time for the relevant activities. The earliest start and finish times of each activity are determined by working forward through the network and determining the earliest time at which an activity can start and finish considering its predecessor activities.

The latest start and finish times are the latest times that an activity can start and finish without delaying the project. LS and LF are found by working backward through the network. The difference in the latest and earliest finish or latest and earliest start of each activity is that activity's slack. The critical path then is the path through the network in which none of the activities have slack.

Example 8.2: Illustration of PERT

For the following project details (Table 8.4), PERT chart has to be prepared.

Table 8.4 Project Details

Activity	Immediate Predecessor	Optimistic Time *To*	Most Likely Time *Tm*	Pessimistic Time *Tp*	Expected Time *Te*	σ	V
ⓐ	-	10	22	22	20	2	④
b	-	20	20	20	20	0	0
c	-	4	10	16	10	2	4
ⓓ	a	2	14	32	15	5	㉕
e	b,c	8	8	20	10	2	4
f	b,c	8	14	20	14	2	4
g	b,c	4	4	4	4	0	0
h	c	2	12	16	11	2.32	5.4
i	g,h	6	16	38	18	5.33	28.4
ⓙ	d,e	2	8	14	8	2	④

PERT Network diagram showing activities, ES, EF in *forward pass* is shown in Figure 8.7.

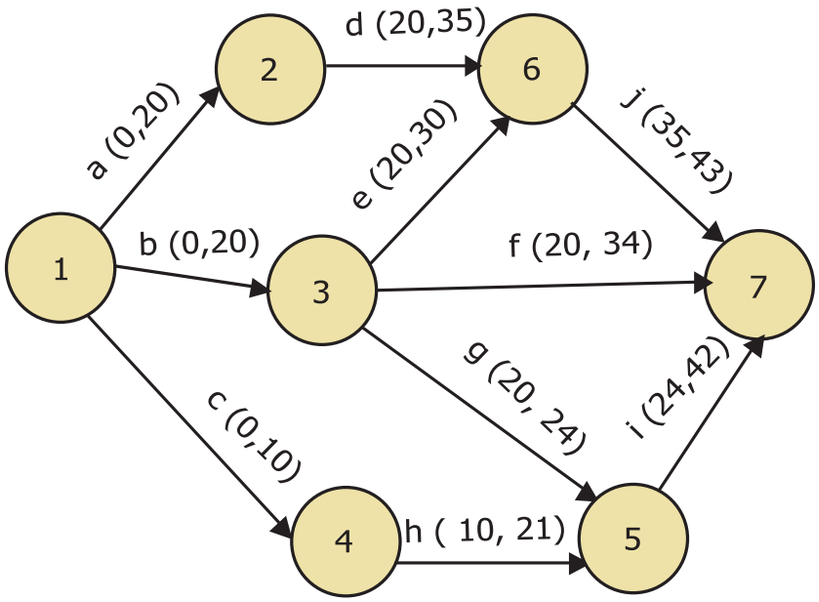


Figure 8.7 ES and EF for Network in Forward Pass

PERT Network diagram showing LS, LF in *backward pass* is shown in the Figure 8.8.

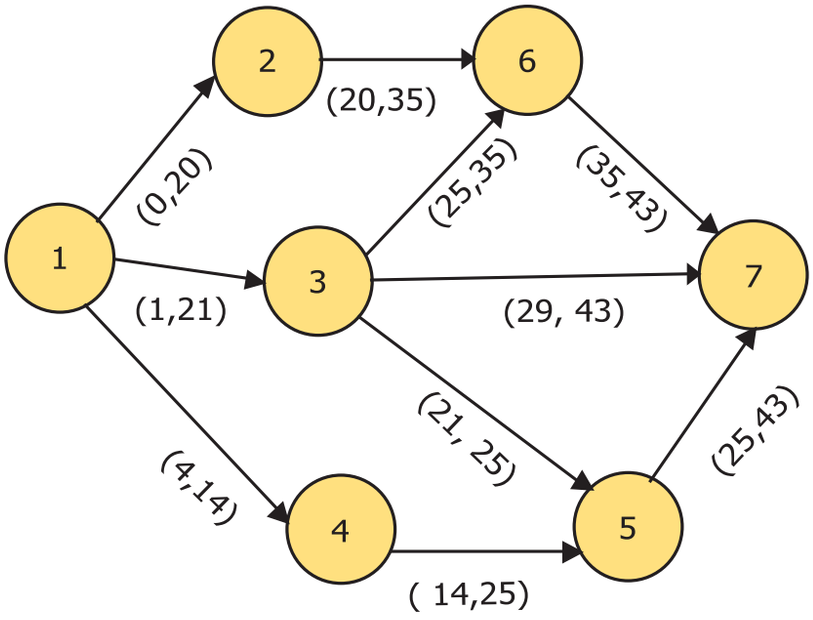


Figure 8.8 LS and LF for Network in Backward Pass

The details of network calculations from forward and backward pass are summarized in Table 8.5

Table 8.5 Summary of Project Calculations

Activity	Expected Time	Earliest Start ES	Earliest Finish EF	Latest Start LS	Latest Finish LF	Float or Slack LS-ES or LF-EF	Critical Path
a	**20**	**0**	**20**	**0**	**20**	**0**	**Yes**
b	20	0	20	1	21	1	
c	10	0	10	4	14	4	
d	**15**	**20**	**25**	**20**	**35**	**0**	**Yes**
e	10	20	30	25	35	5	
f	14	20	34	29	43	9	
g	4	20	24	21	25	1	
h	11	10	21	14	25	4	
i	18	24	42	25	43	1	
j	**8**	**35**	**43**	**35**	**43**	**0**	**Yes**

Critical path: a, d, j = 43 days

Such PERT chart is not final. It may be necessary to make adjustment in PERT chart as project progresses. As the project unfolds, the estimated times can be replaced with actual times. In cases where there are delays, additional resources may be needed to stay on schedule and the PERT chart may be modified to reflect the new situation.

Benefits of PERT

PERT is useful because it provides the following information:

- Expected project completion time.
- Probability of completion before a specified date.
- The critical path activities that directly impact the completion time.
- The activities that have slack time and that can lend resources to critical path activities.
- Activities start and end dates.

Limitations of PERT

- The activity time estimates are somewhat subjective and depend on judgment.
- Even if the activity times are well-estimated, PERT assumes a beta distribution for these time estimates, but the actual distribution may be different.
- Even if the beta distribution assumption holds, PERT assumes that the probability distribution of the project completion time is the same as that of the critical path. Because other paths can become the critical path if their associated activities are delayed, PERT consistently underestimates the expected project completion time.

8.4 Implementation Plan for Top Management

Implementation is the stage where all the planned activities are put into action. Before the implementation of a project, the top management should identify their strength and weaknesses (internal forces), opportunities and threats (external forces).

The strength and opportunities are positive forces that should be exploited to efficiently implement a project. The weaknesses and threats are hindrances that can hamper project implementation. The implementers should ensure that they devise means of overcoming them.

Monitoring is important at this implementation phase to ensure that the project is implemented as per the schedule. This is a continuous process that should be put in place before project implementation starts.

As such, the monitoring activities should appear on the work plan and should involve all stake holders. If activities are not going on well, arrangements should be made to identify the problem so that they can be corrected. When implementation of the project is not on target, there is a need for the project managers to ask themselves and answer the question, "How best do we get there?"

The implementation plan should include a project schedule or timeline. The level of detail included in a schedule depends upon the role of individual on the project. The Table 8.6 shows an example of high-level schedule that was developed by boiler engineer.

Table 8.6 Sample of Project Schedule

Date of Completion	Milestone
June 1	Delivery of boiler components
July 25	Completion of erecting
August 10	Completion of auxiliaries
August 15	Boiler testing and commissioning

8.5 Planning Budget

The project budget will be used throughout the remainder of the project to track project, expenses and measure the money actually spent on project activities against the estimates given for those activities. The final budget figures are based on estimates provided by the project team, key stakeholders, vendors, and others after careful review of the Planning documents.

Most of the costs expended on the project, known as project costs, are fairly obvious and apply to most projects. For example, salaries, office supplies, and telephone charges will apply to almost all projects. These project costs and most others fall into one of three categories: human resource costs, administrative costs, or resource costs.

Human Resource Costs are the costs associated with the personnel on the project. They include salaries and the cost of benefits (such as vacation rime and health insurance).

Administrative costs are the everyday costs that support the work of the project but are not necessarily directly related to a specific task on the project. Local telephone expense, copier paper, heating expenses, and support personnel are examples of administrative costs.

Resource costs include things such as materials needed for specific tasks, equipment leases, long-distance telephone expense, travel expenses, and so on. These expenses are specific to the project.

Direct Costs versus Indirect Costs

In addition to the three categories of project costs, there are also two types of costs: direct and indirect costs. Direct costs include costs such as salaries, equipment rentals, and training for team members. Any cost that can be directly attributed to project work is a direct cost.

Indirect costs are not specific to the project. For example, project team may work with other members of the organization (who are not working on the project) in the same building. The lease cost for the building is an example of an indirect cost because it is not specifically related to the project since all the company employees work there.

Another example of an indirect cost is administrative staff, managers, or other functional members who will be assisting the project team with project activities (such as someone from the procurement department) but are not assigned tasks themselves. Each organisation has its own procedures for accounting for indirect costs. Finance or Accounting Department can provide guidance on how indirect cost should be accounted for in the project budget.

Budget Estimation

If the project ends up as an unsuccessful project, one of the reasons could be inadequate budget. The responsibility for determining project cost lies mostly with finance manager and he gets approval from senior management. The project manager is told about the final budget and is expected to work with the allocated budget. If this is the case, project manager can contribute to budgeting process by using his communication and negotiation skills with finance manager.

The first step in creating the project budget is to gather all the Planning documents for reference. The project goals and deliverables for obvious budget expenses have to be reviewed. The WBS, network diagram also has to be reviewed to identify costs associated with them.

The WBS is used to identify, estimate, and assign costs to each element of the project. The work package level is where individual costs and estimates for each task (provided the work package level shows tasks) are shown, whereas the higher levels in the WBS will show rolled-up total costs.

Analogous Estimating establishes an estimate for the current project based on the actual costs of previous projects that are similar in size and scope to the ongoing project. Bottom-up Estimating establishes individual estimates for each tasks and adds them all together to determine the total estimate for the project.

8.6 Procurement Procedures

Many organizations have a procurement department that will help you purchase the items needed for your protect. They may also help you create the budget. Always check with the procurement department to determine whether there are procedures you should follow when preparing your budget. Also be certain to work with the procurement department when purchasing services from vendors or contractors.

8.7 Construction

Project construction is the process of assuring that all systems and components of an industrial equipment are designed, installed, tested, operated, and maintained according to the operational requirements of the user. A commissioning process may be applied not only to new projects but also to existing units and systems subject to expansion, renovation or revamping.

In practice, the commissioning process comprises the integrated application of a set of engineering techniques and procedures to check, inspect and test every operational component of the project, from individual functions, such as instruments and equipment, up to complex amalgamations such as modules, subsystems and systems.

Commissioning activities, in the broader sense, are applicable to all phases of the project, from the basic and detailed design, procurement, construction and assembly, until the final handover of the unit to the owner, including sometimes an assisted operation phase.

8.8 Measurement and Verification

Measurement and Verification (M&V), sometimes also referred to as monitoring and verification, is a process, which is used to determine energy and demand savings. The primary application of M&V is in those energy efficiency projects where the return on the capital investment is tied to the projected energy savings that will be achieved. M&V becomes a central part of a contract if the contract payments or performance guarantee in a project are dictated by the magnitude of the energy savings that will result from the implementation of a set of energy efficiency measures. M&V is primarily focused on risks that affect the measurement or determination of savings from energy or water efficiency programs. These risks are defined in the terms of the contracts between the participants.

Energy or demand savings are determined by comparing measured energy use or demand before and after implementation of an energy savings program. In general:

Energy Savings = Base year Energy Use – Post-Retrofit Energy Use ± Adjustments

The "Adjustments" term in this general equation brings energy use in the two time periods to the same set of conditions. Conditions commonly affecting energy use are weather, occupancy, plant throughput, and equipment operations required by these conditions. Adjustments may be positive or negative.

Adjustments are derived from identifiable physical facts. The adjustments are made either routinely such as for weather changes, or as necessary such as when a second shift is added, occupants are added to the space, or increased usage of electrical equipment in the building. Adjustments are commonly made to restate base year energy use under post-retrofit conditions.

Solved Example:

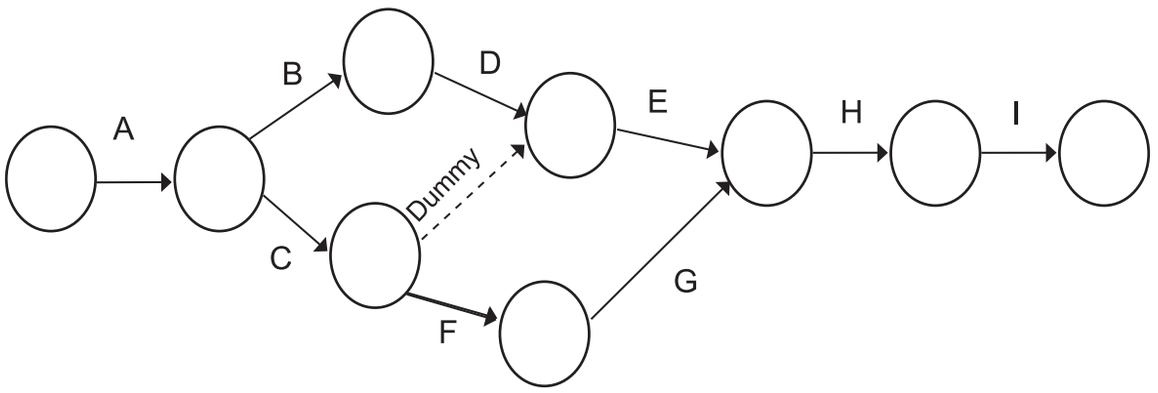
For the following tasks, durations, and predecessor relationships in the following activity table,

Activity Description	Immediate Predecessor(s)	Optimistic (Weeks)	Most Likely (Weeks)	Pessimistic (Weeks)
A	---	4	7	10
B	A	2	8	20
C	A	8	12	16
D	B	1	2	3
E	D, C	6	8	22
F	C	2	3	4
G	F	2	2	2
H	E, G	4	8	12
I	H	1	2	3

a) Draw the network
b) Calculate expected time for all tasks
c) Calculate variance for all tasks
d) Determine all possible paths and their estimated durations
e) Identify the critical path

Ans:

a) Network diagram is shown below:



(b) & (c) Expected Time & Variance:

$T_e = (T_o + 4\,T_m + T_p)/6$

$\sigma = (T_p - T_o)/6$

$V = ((T_p - T_o)/6)^2$

Activity Description	Immediate Predecessor(s)	Optimistic (Weeks)	Most Likely (Weeks)	Pessimistic (Weeks)	Expected Time T_e	Variance (V)
A	---	4	7	10	7	1.00
B	A	2	8	20	9	9.00
C	A	8	12	16	12	1.78
D	B	1	2	3	2	0.11
E	D, C	6	8	22	10	7.11
F	C	2	3	4	3	0.11
G	F	2	2	2	2	0.00
H	E, G	4	8	12	8	1.78
I	H	1	2	3	2	0.11

d)

A - B – D – E – H –I	7+9+2+10+8+2 = 38
A – C – E – H – I	**7+12+10+8+2 = 39**
A – C – F – G – H – I	7+12+3+2+8+2 = 34

The critical path is A – C – E – H – I

e) Duration of critical path is 39 weeks.

QUESTIONS	
Objective Type Questions	
1.	An activity in a project has an optimistic time of 10 days, a most likely time of 15 days and a pessimistic time of 20 days. Its expected time of completion is _____ a) 10 days b) 15 days c) 30 days d) 35 days.
2.	Network diagrams show logic clearly but does not have _____ like Gantt chart. a) nodes b) arrows c) time scale d) events
3.	To judge the attractiveness of any investment, the project manager must consider: a) Initial capital cost b) Net operating cash inflows c) salvage value d) all the above
4.	The Critical Path in PERT indicates _____. a) minimum time required for the completion of the project b) delays in the project c) maximum time required for the completion of the project d) none of the above
5.	The time between its earliest and latest start time, or between its earliest and latest finish time of an activity is _____ a) delay time b) slack time c) critical path d) start time
6.	In project management work breakdown structure defines a) temporary endeavour undertaken to create unique product or service b) the activities to be completed in the projects c) how realistic were the assumptions underlying the project d) none of the above
7.	In project management, the critical path in the network is a) the path where activates have slack b) the shortest path c) the path where no activities have slack d) none of the above
8.	The technique used for scheduling the tasks and tracking of the progress of energy management projects through a bar chart is called a) CPM b) Gantt chart c) CUSUM d) PERT
9.	Which of the following statements is correct regarding 'float' for an activity? a) Time between its earliest start time and earliest finish time b) Time between its latest start time and latest finish time c) Time between latest start time and earliest finish time d) Time between earliest finish time and latest finish time

10.	An activity has an optimistic time of 15 days, a most likely time of 18 days, and a pessimistic time of 27 days. What is the expected time? a) 60 days b) 20 days c) 19 days d) 18 days
Short Type Questions	
S-1	What is the importance of slack time in project network
S-2	What are the limitations of PERT?
S-3	Explain the following a) Guaranteed saving performance contract b) Shared savings performance contract
S-4	Define activity, event and network?
S-5	What is the essential difference between CPM and PERT?
Long Type Questions	
L-1	Construct a PERT Diagram for the following project and find out the critical path.

Activity	Duration in weeks	Precedent
A	7	Start
B	3	A
C	1	B
D	8	A
E	2	D,C
F	1	D,C
G	1	D,C
H	3	F
I	2	H
J	1	E,G,I

i) Draw the PERT network,
ii) What is the critical path?
iii) What is the total duration required to complete the project?
iv) What is the available slack in each of the activity?

L-2

(i) Construct a PERT diagram for the data given below

(ii) Identify the critical path. Also compute the earliest start, earliest finish, latest start & latest finish of all activities

Activity	Precedent	Time, weeks
A	Start	3
B	A	4
C	A	1
D	C	3
E	Start	2
F	B	2
Finish	D, E, F	--

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Chapter 9

Energy Monitoring and Targeting

Learning Objectives

In this chapter you will learn about

- Importance of energy monitoring and targeting
- Elements of monitoring and targeting systems
- Relating energy consumption and production
- Using graphical tools for trends and projections
- CUSUM technique
- Energy management information system

9. ENERGY MONITORING AND TARGETING

Defining monitoring and targeting, Elements of monitoring and targeting, Data and information analysis, Techniques-energy consumption and production, Cumulative sum of differences (CUSUM), EMIS.

9.1 Introduction

It is possible to establish the existing energy consumption of a facility or organization through an energy audit. However, this only produces a 'picture' of past energy consumption. In order to keep control of subsequent energy consumption, it is necessary to initiate a monitoring programme. However, monitoring programme alone has limited value as it simply records energy consumption. To achieve improvements in energy performance, a targeting programme, in which targets are set, must accompany the monitoring process and planned improvements made.

Energy monitoring and targeting (M&T) is primarily a management technique that uses energy information as a basis to eliminate waste, reduce and control current level of energy use and improve the existing operating procedures. It is based on the principle **"you can't manage what you don't measure**". It essentially combines the principles of energy use and statistics.

By using M&T, all plant and building utilities such as fuel, steam, refrigeration, compressed air, water, effluent, and electricity are managed as controllable resources in the same way that raw materials, finished product inventory, building occupancy, personnel and capital are managed.

Monitoring and Targeting (M&T) programs have been so effective that they show typical reductions in annual energy costs in various industrial sectors between 5 and 15%.

9.2 What is Monitoring & Targeting?

Monitoring is the process of establishing the existing pattern of energy consumption and explaining deviations from existing pattern. Its primary goal is to maintain existing pattern by providing all the necessary data on energy consumption and key related data such as production.

Targeting is the identification of desirable energy consumption level and working towards achieving them. Targets are based on the historical (average or best) data acquired during the monitoring as well as benchmarking with energy performance of similar organizations.

9.3 Setting up Monitoring & Targeting

Before initiating M&T, it is important to establish Energy Account Centers (EACs) within an organization. These may be departments, processes or cost centers. Operational managers should be accountable for the energy consumption of the EACs for which they are responsible.

It is important that any proposed M&T programme be designed to suit the needs of the particular organization. From an energy point of view, organization can be characterized in various ways. Typical classifications are by the number of sites covered and the level of metering adopted as follows:

- ✓ Single site with central utility metering
- ✓ Single site with sub-metering
- ✓ Multi-site with central utility metering
- ✓ Multiple-site with sub-metering

Single site with central utility metering are probably best treated as a single EAC, while the introduction of sub-metering enables such site to be broken-up into a number of separate EACs. Where the organization has a number of separate sites, each with central utility meters, the sites should be treated as separate EACs. If the organization has multiple sites, each containing sub-metering, then it should be possible to divide each site into a number of separate EACs.

9.4 Key Elements of Monitoring & Targeting System

The key elements of M&T system are:

- ✓ **Recording -**Measuring and recording energy consumption of each EAC within an organization. This involves setting up procedures to ensure regular collection of reliable energy data.

- ✓ **Analysing & Comparing –**Relating energy consumption to a measured output, such as production quantity for 12-24 months of historical data to obtain standard energy performance for each EAC. Standard energy performance is established through regression analysis of past data. If these data do not exist, then it will be necessary to conduct an energy audit to establish standard energy performance. Standard Energy Performance provides a *base line* for the assessment of future performance. It can also be used as an initial target.

- ✓ **Setting Targets -**Setting energy targets for each EAC. Energy cost savings can be consistently achieved if improvements are made on standard energy performance. Achievable targets should therefore be set which improve on standard energy performance. Targets can be set based on external benchmarking with other similar organization or historical achievement of least energy consumption in the same organization.

- ✓ **Monitoring -**Comparing actual energy consumption to the set target on a regular basis

- ✓ **Reporting -**Reporting the results to management including any variances from the targets which have been set and related performance problems in equipment and systems. Energy management reports should be produced for each EAC on a regular basis. These reports provide the stimulus for improved energy performance, and should also quantify any improvements that are achieved.

- ✓ **Controlling -**Implementing management measures to correct any variances, which may have occurred

Particularly M & T system will involve the following:

- **Checking** the accuracy of energy invoices
- **Allocating** energy costs to specific departments (Energy Accounting Centres)
- **Determining** energy performance / efficiency
- **Recording** energy use, so that projects intended to improve energy efficiency can be checked for results.
- **Highlighting** performance problems in equipment or systems

Benefits of M&T

The ultimate goal is to reduce energy costs through improved energy efficiency and management control measures. Other benefits include:

- ✓ Identify and explain an increase or decrease in energy use
- ✓ Draw energy consumption trends (weekly, seasonal, operational)
- ✓ Improve energy budgeting corresponding to production plans
- ✓ Observe how the organization reacted to changes in the past
- ✓ Determine future energy use when planning changes in operations
- ✓ Diagnose specific areas of wasted energy
- ✓ Develop performance targets for energy management programs / energy action plans
- ✓ Manage energy consumption rather than accept it as a fixed cost that cannot be controlled.

9.5 Data and Information Sources

Information related to energy use may be obtained from following sources:

- ✓ **Plant level** information can be derived from financial accounting systems—utilities cost centre
- ✓ **Plant department level** information can be found in comparative energy consumption data for a group of similar facilities, service entrance meter readings etc.
- ✓ **System level** (for example, compressor house) performance data can be determined from sub-metering data
- ✓ **Equipment level** information can be obtained from nameplate data, run-time and schedule information, sub-metered data on specific energy consuming equipment.

All of these data are useful and can be processed to yield information about facility performance.

9.6 Data and Information Analysis

There are a wide variety of statistical and numerical techniques which can be used to understand why energy is consumed in a particular way. Some of the analysis techniques are fairly simple and can be done with hand calculator, the others are more complex and may require use of information technology. The various analysis techniques are explained as follows:

Annual Energy Consumption

The simplest analysis is to produce percentage breakdown of annual energy consumption and cost data. This is a useful technique which enables to assess overall energy performance of a plant or building quickly and easily. The analysis of annual energy consumption should be carried out as follows:

1. Convert all the energy consumption data into standard units (usually the kcal) using the standard energy conversions shown in Table 9.1.
2. Compile the data as shown in Table 9.2 showing the annual energy consumption and cost for various fuel and energy types.
3. Compile the above information to produce percentage breakdown of the total energy consumption and cost of each energy type (Table 9.3).
4. Produce pie-charts similar to those shown in Figure 9.1 and Figure 9.2 to show graphically the energy and cost contribution of each energy type
5. Similar procedure can be followed for previous years to identify trends.

Table 9.1 Standard Energy Conversions

Energy source	Supply unit	Conversion Factor to kcal
Electricity	kWh	860
HSD	kg	10,500
Furnace Oil	kg	10,200
LPG	kg	12,000

Table 9.2 Annual Energy Consumption and Cost for Various Fuels and Energy Types

Month	Thermal Energy					Electrical Energy					Total Energy Bill
	Furnace Oil	LPG	HSD	Total Thermal Consum-ption	Total Thermal Bill	Day	Night	Total Electricity Consum-ption	Maximum Demand	Total Electricity Bill	
	kcal	kcal	kcal	kcal	Rs. Lakh	kWh	kWh	kWh	kVA	Rs.Lakh	Rs. Lakh
1											
2											
3											
…..											
…..											
11											
12											
Sub-Total											
%											

Table 9.3 Example of % Breakdown of Energy Consumption & Costs

Energy Type	Purchased units	Consumption		Cost	
		kcal	%	Rs.	%
Electricity	1570	1350200	18	6280	20
HSD	36	378000	5	1620	5
Furnace Oil	456	4651200	62	20520	66
	110	1320000	15	2750	9

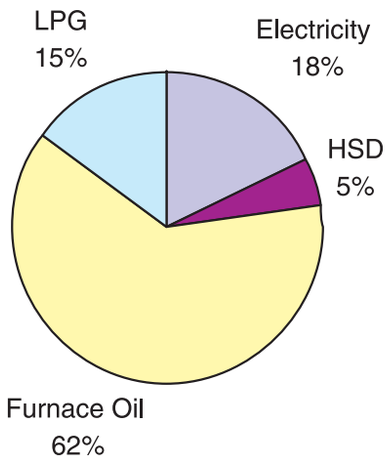

Figure 9.1 % Share of Energy

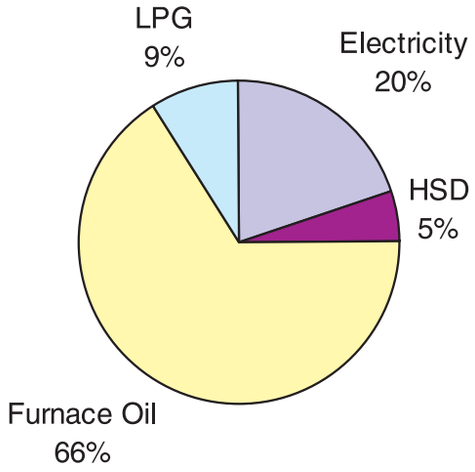

Figure 9.2 % Share of Cost

It may be noted that this simple analysis identifies energy consumption and cost breakdown and trends and does not make any allowance for variable factors which may influence energy consumption e.g. climatic zones or occupancy for buildings. Hence, this analysis cannot be used as a comparison tools between different organizations.

Annual Energy Consumption Using Bar Chart

If 24 months of energy data is collated, the annual energy consumption can be represented in form of bar chart. The most common bar chart application used in energy management is one showing the energy per month for current year and previous year (see Figure 9.3) – however, this chart does not tell us clearly about any trends in energy consumption.

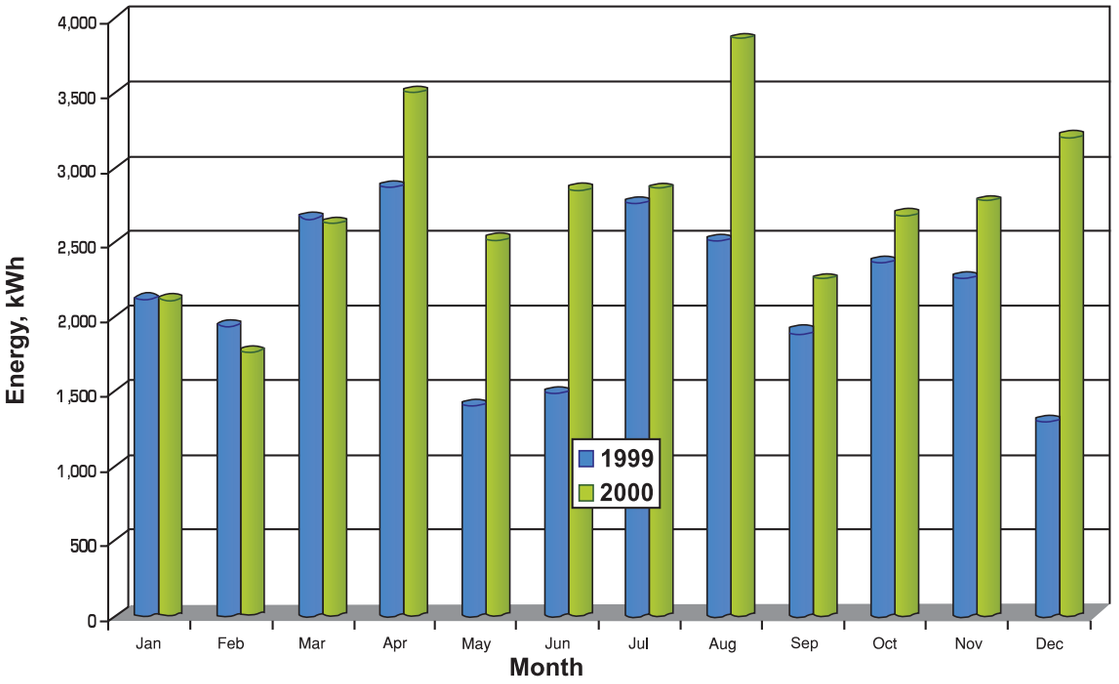

Figure 9.3 Energy Consumption: Current Year Vs. Previous Year

Time-dependent Energy Analysis

If monthly energy consumption data is collected, it is possible to produce a simple graph in which energy consumption is plotted against time (Figure 9.4). Through this simple time-dependent analysis, it is possible to identify general trends and seasonal patterns in energy consumption. This enables exception to the norms to be identified immediately.

The limitations of this tool are that it is difficult to find out why certain trends occur or if a particular trend is there or not. Although, this tool is useful, it can be used only as a comparative tool and not an absolute one.

Consider Figure 9.4, the time dependent graph shows monthly electricity consumption for the years 2008 and 2009. It can be seen from the graph that:

- Electricity consumption during the months of January, February and March of 2009 is consistently less than in the corresponding period of 2008.
- The base load electricity consumption is approximately 10,500 kWh/month.
- Energy consumption during the months of November and December 2009 and January 2010 appears to have increased significantly compared with the corresponding 2008 figures. This tends to indicate loss of control over electricity consumption.

However, it is impossible to identify why the energy consumption for January, February and March 2009 is lower than for the same period in 2009. In order to do so, further analysis is needed.

It is possible to plot more than one variable using this chart, for example, oil consumption along with electricity consumption data.

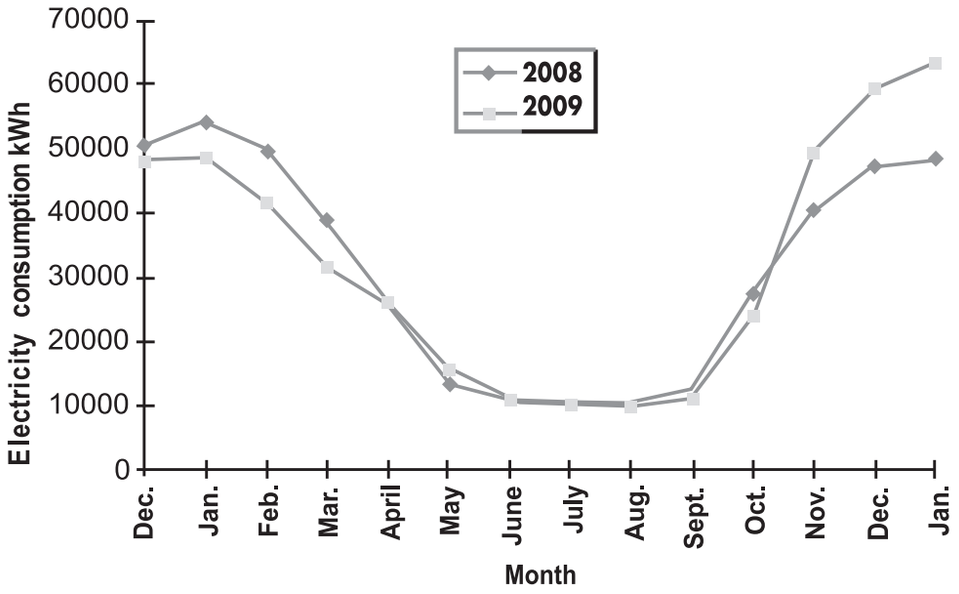

Figure 9.4 Monthly Electricity Consumption

Norm Chart

The norm chart is a sequential plot of actual energy consumption overlaid on a plot of target consumption. It is of little value as an analytical tool, but can be useful for highlighting exceptions and communicating these to managers. Because norm charts represent a historical record of energy consumption, senior and operational managers find them relatively easy to understand. Refer Figure 9.5.

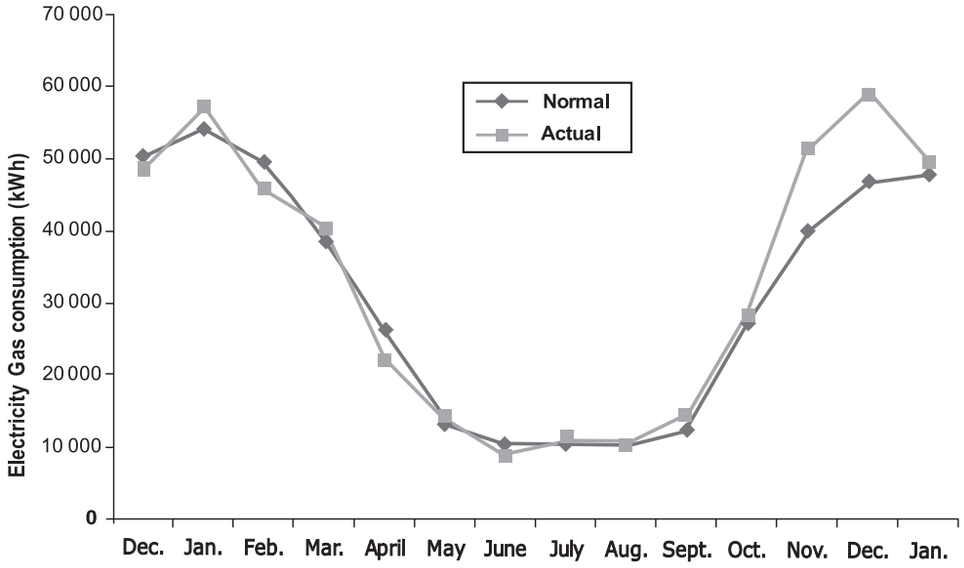

Figure 9.5 Norms Chart for Gas Consumption

Deviance Chart

Deviance charts plot the difference between target and actual energy consumption (see Figure 9.6). If, in any one month, energy consumption is above the target value, then the consumption is plotted as a positive value; by contrast a negative value is returned if actual consumption is lower than predicted. When producing a deviance chart it is useful to show on the graph limits of normal operation, since this helps to distinguish between normal limits and serious deviations from the norm. Deviance charts are particularly good at highlighting problems, so that remedial action can be taken. They can also be used to initiate detailed exception reports.

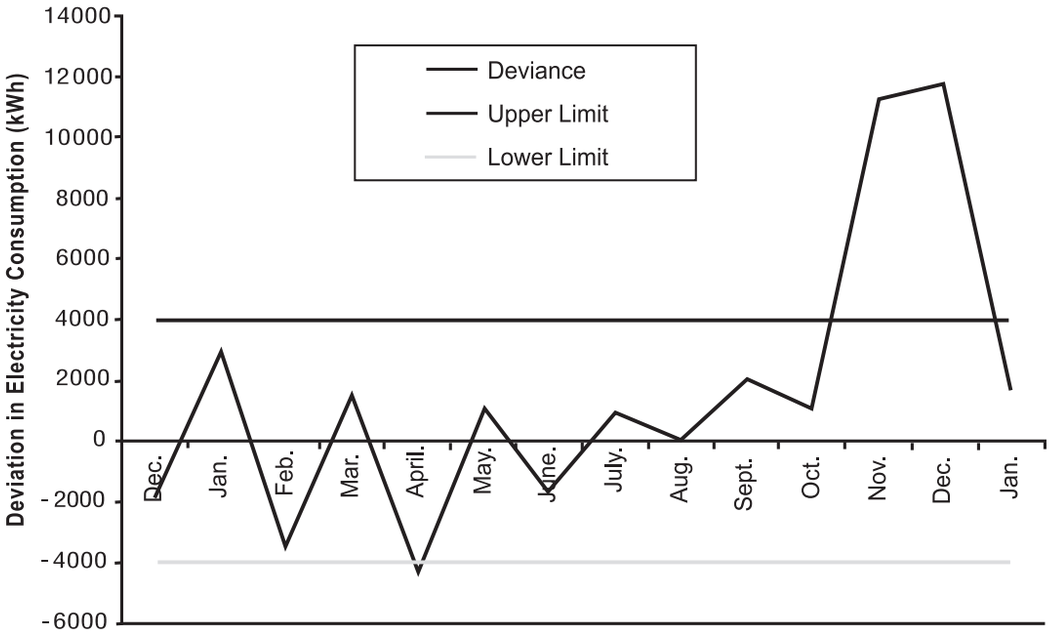

Figure 9.6 Deviance Chart for Gas Consumption

Relating Annual Energy and Production using Bar Chart

If related production data is also available for the same 24 months period, we know that the levels of production may have effect on energy consumption and hence specific energy consumption can be calculated and plotted as bar chart as shown in Figure 9.7. The chart shows some trends – an all time low in December followed by rising trend in specific energy consumption.

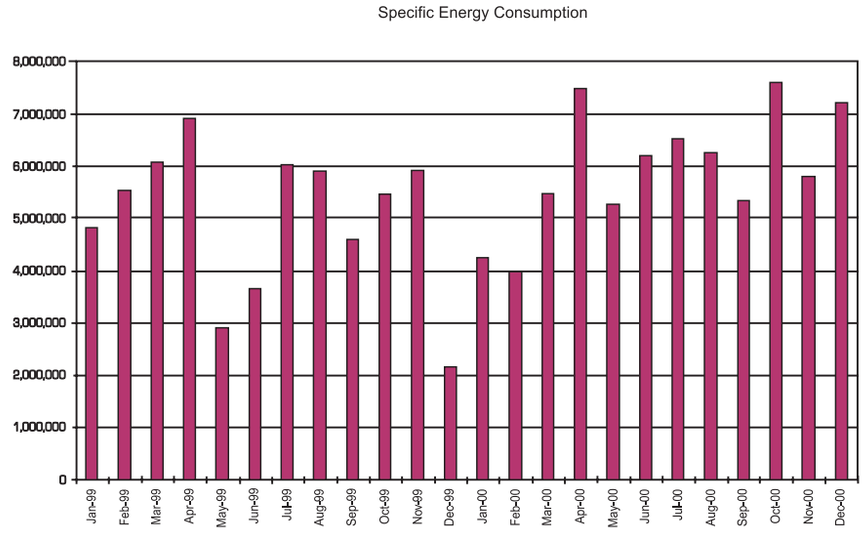

Figure 9.7 Monthly Specific Energy Consumption

If production levels are added to SEC chart as in Figure 9.8, the features of the chart become clearer. For example, the very low SEC occurred when there was a record level of production. This indicates that there might be fixed energy consumption –i.e. consumption that occurs regardless of production levels.

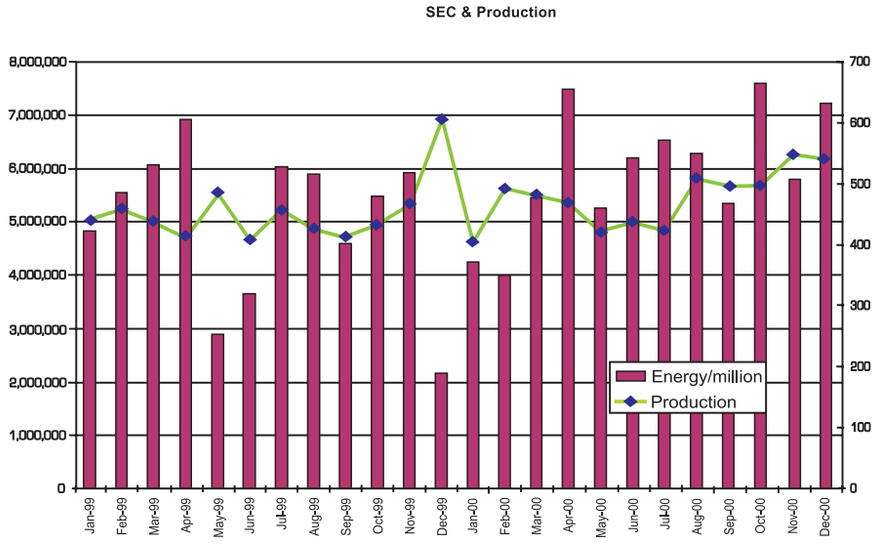

Figure 9.8 SEC with Production

Moving Annual Total

Another way of representing energy and production data is in form of a *Moving Annual Total.* If 12 months of energy and production data are available, we can plot the chart. For this chart, each point represents the sum of previous 12 months of data. In this way, each point has full range of the seasons, holidays. The technique also smoothes out errors in the timings of meter readings

If energy and production are plotted in the same chart and are tracking each other as shown in Figure 9.9, it suggests that there is no cause for alarm. Any deviations in energy line has to be watched so as to identify early warning of energy waste or to confirm that energy efficiency measures are making a positive impact.

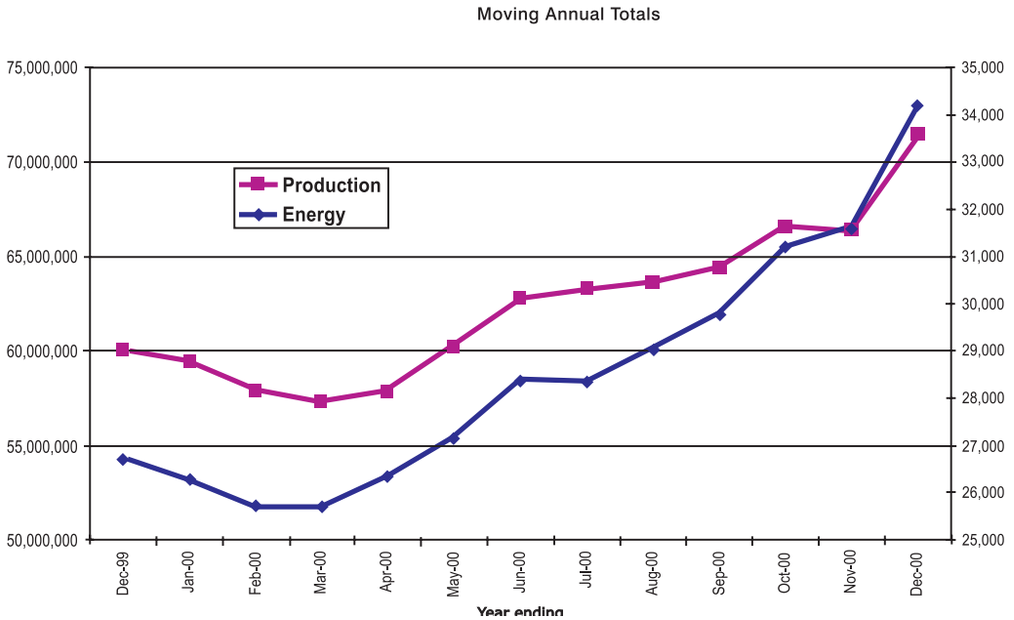

Figure 9.9 Moving Annual Total – Energy and Production

Linear Regression Analysis

Linear regression analysis is a statistical technique which determines and quantifies the relationship between variables. It is a widely used energy management tool which enables standard equations to be established for energy consumption, often from data which would otherwise be meaningless.

Regression analysis overcomes the limitation of time-dependent analysis by removing the 'time' element from the analysis and focusing instead on the variables which influence energy consumption. It is a versatile technique which can be used to analyse a wide variety of applications. When used as an energy management tool, the variables commonly compared are:

- Furnace Oil consumption versus the number of units of production.
- Electricity consumption versus the number of units of production.
- Water consumption versus the number of units of production.
- Electricity consumed by lighting versus hours of occupancy.

Regression analysis is very much dependent on the quality of the data used. It should therefore be treated with care. If an analysis indicates the absence of a significant relationship between two variables, it does not necessarily mean that no relationship exists. The significance of results depends on the quantity and quality of the data used, and indeed, on the variables used in the analysis. Table 9.4 shows a selection of factors which can influence energy and water consumption.

Table 9.4 Factors which influence Energy Consumption

Energy	Purpose	Influencing Factors
Electricity	Air compressors	Air volume delivered
Furnace oil	Steam raising in boilers	Amount of steam generated
Steam	Production process	Production volume

a) Single Independent Variable

XY Scatter Diagram

XY Scatter Diagram provides more understanding of relationship between energy and production. A sample XY Scatter Diagram is shown in Figure 9.10.

This chart shows a low degree of scatter indicative of a good fit. If data fit is poor, it indicates poor level of control and hence a scope for energy savings. If data fit is poor and if it is known that there should be a relationship, it indicates a poor level of control and hence a potential for energy savings. In producing the production/energy relationship chart a relationship relating production and energy consumption is obtained.

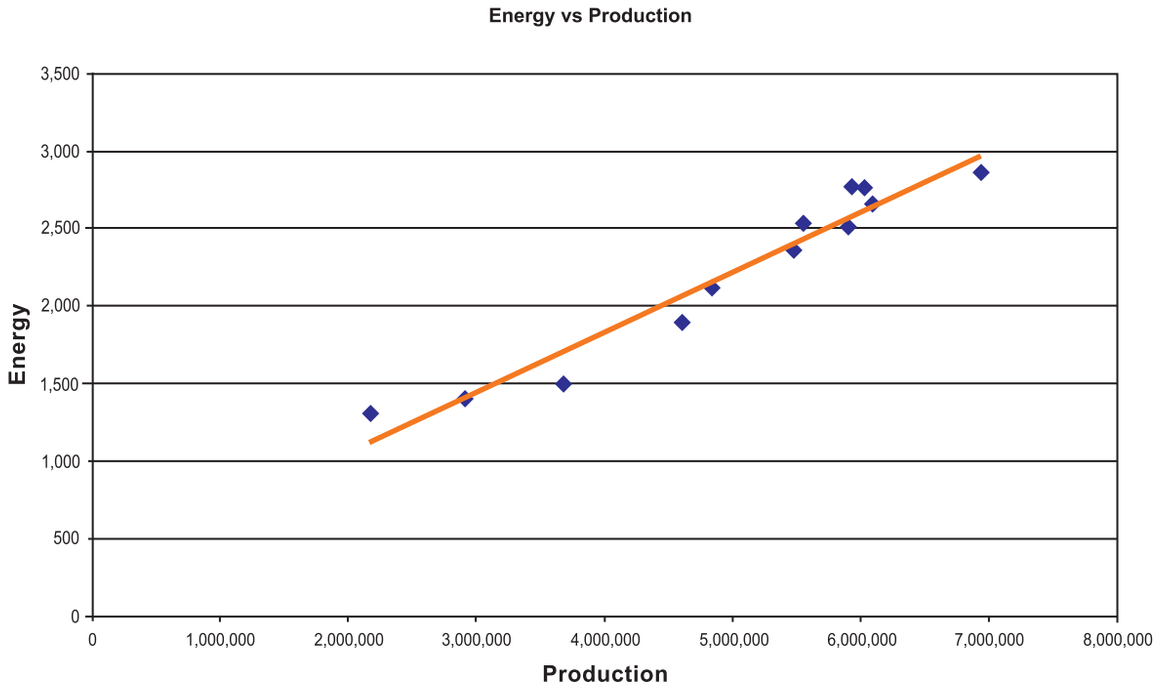

Figure 9.10 XY Chart for Energy-Production Relationship

For example if energy consumption in tones of oil equivalent (i.e. a dependent variable) and production in Metric tonnes (i.e. an independent variable) in a foundry furnace are plotted against each other on a graph some sort of relationship between the two can be obtained.

This relationship is in fact linear and it is possible to derive an equation for the *best-fit* straight-line curve through the points plotted on the graph. The *best-fit* straight-line curve is determined by summing the squares of the distances from the straight line of the various data points. Once established, this linear equation can be used to predict future energy consumption. In addition, it can be used as a *standard performance* equation for energy *monitoring and targeting* purposes.

The generic equation for a straight-line graph can be represented as:

$y = c + mx$

Where y is the dependent variable (e.g. energy consumption), x is the independent variable (e.g. production), c is the value at which the straight-line curve intersects the 'y' axis, and m is the gradient of the straight-line curve.

In other words

Energy consumed for the period = C + m x production for the same period

If the straight line y = c + *mx* is best fitted to a set of data sample points; it can be shown that

$$(x_1, y_1) . (x_2, y_2) ..... (x_n, y_n)$$

and

$$cn + m\Sigma x = \Sigma y$$

$$c\Sigma x + m\Sigma x^2 = \Sigma xy$$

Where n is the number of data points.

These equations are known as the normal equations of the problem and they can be used to establish the values of c and m, as illustrated in the following Example 9.1.

Example

Consider a foundry which during a monitoring programme produces the following sample data:

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Production, Tonnes/month, x	380	440	460	520	320	520	240	620	600
Energy use, Toe/month, y	340	340	380	380	300	400	280	424	420

Therefore:

n	*x*	*y*	x^2	*xy*
1	380	340	144400	129200
2	440	340	193600	149600
3	460	380	211600	174800
4	520	380	270400	197600
5	320	300	102400	96000
6	520	400	270400	208000
7	240	280	57600	67200
8	620	424	384400	262880
9	600	420	360000	252000
	4100	**3264**	**1994800**	**1537280**

Therefore, the normal equations become

$9c + 4100m = 3264$

$4100c + 1994800m = 1537280$

Therefore

$$c = \frac{3264 - 4100m}{9}$$

Therefore

$$4100\ (3264\text{-}4100m)/9 + 1994800m = 1537280$$

$$1486933 - 1867778m + 1994800m = 1537280$$

$$127022m = 50347$$

$$m = 0.4$$

and $c = 180$

The best fit straight line equation is therefore:

$$y = 180 + 0.4\,x$$

From this equation, it can be seen that the theoretical base load for furnace is 180 mtoe.

The same relationship can be obtained by plotting in a graph as shown in Figure 9.11.

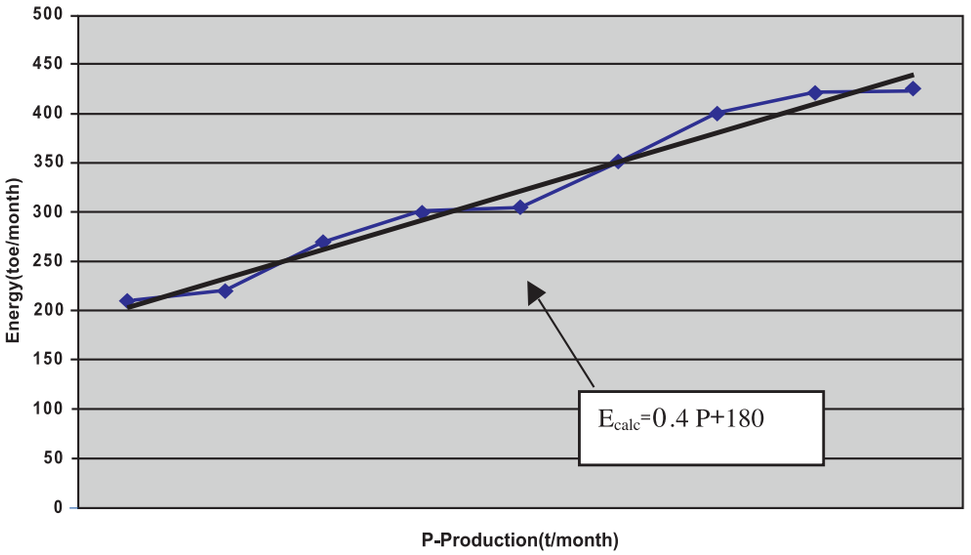

Figure 9.11 Energy-Production Relationships for Foundry

Correlation Coefficients

The regression analysis method described in Section 4.5.1 enables a *best-fit* straight line to be determined for a sample data set. However, in some circumstances the sample data points may be very scattered with the result that the derived equation may be meaningless. It is therefore important to determine how well the *best-fit* line correlates to the sample data. This can be done by calculating the Pearson correlation coefficient, which gives an indication of the reliability of the line drawn. The Pearson correlation coefficient is a value between 1 and 0, with a value of 1 representing 100% correlation. The Pearson correlation coefficient (r) can be determined using equation (4.4).

$$r = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\sqrt{[\Sigma(x - \bar{x})^2 \Sigma(y - \bar{y})^2]}}$$

Where x, y are the x and y values, and $\bar{x}, \bar{y}$ are the average of x and y values. Example 4.3 illustrates how the correlation coefficient may be calculated.

x	y	$(x - \bar{x})$	$(y - \bar{y})$	$(x - \bar{x})(y - \bar{y})$	$(x - \bar{x})^2$	$(y - \bar{y})^2$
380	340	-75.56	-22.67	1712.59	5708.64	513.7778
440	340	-15.56	-22.67	352.59	241.98	513.7778
460	380	4.44	17.33	77.04	19.75	300.4444
520	380	64.44	17.33	1117.04	4153.09	300.4444
320	300	-135.56	-62.67	8494.81	18375.31	3927.111
520	400	64.44	37.33	2405.93	4153.09	1393.778
240	280	-215.56	-82.67	17819.26	46464.20	6833.778
620	424	164.44	61.33	10085.93	27041.98	3761.778
600	420	144.44	57.33	8281.48	20864.20	3287.111
4100	**3264**	**0**	**0**	**50346.67**	**127022.22**	**20832.00**

Therefore,

$$r = \frac{50346.67}{(127022.22 \times 20832)^{0.5}} = 0.98$$

Table 9.5 shows minimum acceptable correlation coefficients for given numbers of data samples. It can be seen from the Table that the correlation coefficient in Example 9.1 is very good.

Table 9.5 Minimum Correlation Coefficients (r)

Number of data samples	*Minimum correlation coefficient (r)*
10	*0.767*
15	*0.641*
20	*0.561*
25	*0.506*
30	*0.464*
35	*0.425*
40	*0.402*
45	*0.380*
50	*0.362*

b) Multi-variable analysis

Often energy consumption can be influenced by several different variables. When this is the case

the relationship can be described by the equation:

$$y = c + m_1 x_1 + m_2 x_2 + \ldots\ldots + m_n x_n$$

where, x_1, x_2 . . . . . x_n are the variables that influence y.

It is difficult to solve multivariable analysis by hand calculation. It is therefore advisable to use specialist computer software which can be employed to determine the statistical relationship between the variables.

CUSUM Charts

CUSUM is an acronym for **Cu**mulative **Sum** of differences. CUSUM charts can be particularly useful why diagnosing why energy is occurring. This is principally because they identify the *date of any change* in energy performance. It can be particularly helpful to know when a problem first occurred as this helps to pin-point the problem and further analysis can then be made to determine its root cause.

First step is to establish standard energy performance equation through analysis of data (energy and related variable e.g. production) collected during monitoring period before any interventions are made.

It can be used to establish target or baseline against which actual energy consumption can be compared. Second step is to calculate the differences between the standard energy consumption and actual energy consumption. Third step is determining CUSUM which is cumulative summation of differences between actual energy consumption and targets or baseline.

CUSUM values, when plotted against time, not only helps us to know the trends, but also helps to calculate energy savings or losses when performance changes. A typical CUSUM graph follows a trend and shows random fluctuation of energy consumption and oscillation around zero (baseline or standard). This trend will continue until something happens to alter the pattern of consumption such as the effect of an energy saving measure or, conversely, a worsening in energy efficiency (poor control, housekeeping or maintenance).

CUSUM chart (see Figure 9.12) for a generic company is shown. The CUSUM chart shows what is really happening to the energy performance. From the chart, it can be seen that starting from year 2000, performance is better than standard. Performance then declined (line going up) until April, and then it started to improve until July. However, from July onwards, there is a marked, ongoing decline in performance – line going up.

When looking at CUSUM chart, the changes in direction of the line indicate events that have relevance to the energy consumption pattern. Clearly, site knowledge is needed to interpret better events related to energy consumption. For example, if there are planned changes in energy systems, adverse change in performance can be attributed to lack of control, poor housekeeping or improper maintenance.

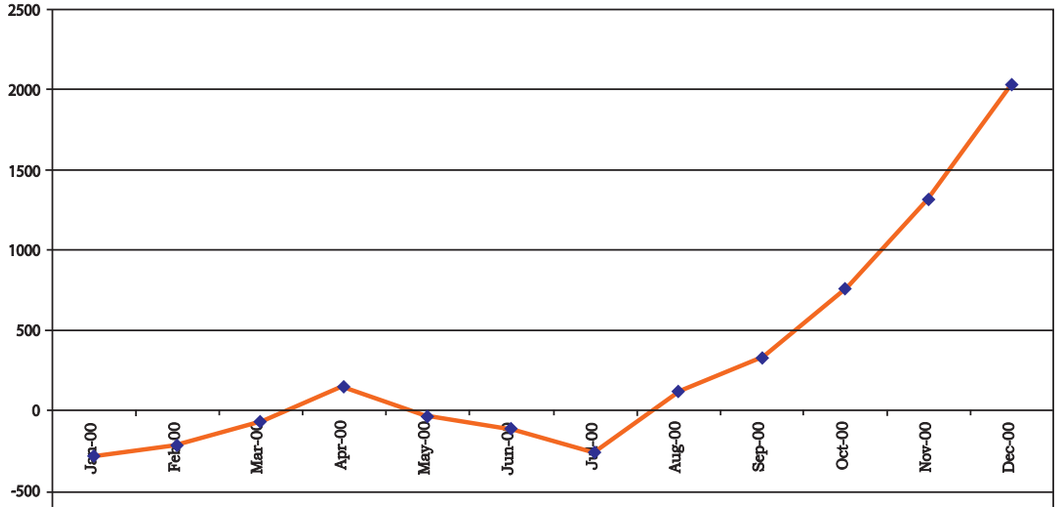

Figure 9.12 Typical CUSUM Chart

Example : CUSUM Technique

Energy consumption and production data were collected for furnace in a foundry over a period of 18 months. During month 9, a heat recovery system was installed. Using the plant monthly data, estimate the savings made with the heat recovery system. The plant data is given in Table 9.6:

Table: 9.6 Month Wise Production with Energy Consumption		
Month	**E_{act} - Monthly Energy Use (toe * / month)**	**P - Monthly Production (tonnes / month)**
1	340	380
2	340	440
3	380	460
4	380	520
5	300	320
6	400	520
7	280	240
8	424	620
9	420	600
10	400	560
11	360	440
12	320	360
13	340	420
14	372	480
15	380	540
16	280	280
17	280	260
18	380	500

***toe = tonnes of oil equivalent.**

Steps for CUSUM analysis

1. Plot the Energy – Production graph for the first 9 months
2. Draw the best fit straight line
3. Derive the equation of the line (Equation derived is E = 0.4 P + 180)
4. Calculate the standard energy consumption based on various production based on the equation
5. Calculate the difference between actual and standard energy consumption
6. Compute CUSUM

These steps are shown in the Table 9.7.

7. Plot the CUSUM graph
8. Estimate the savings accumulated from use of the heat recovery system.

Table 9.7 CUSUM

Month	E_{act}	P	E_{calc} (0.4 P + 180)	$E_{act} - E_{calc}$	CUSUM (Cumulative Sum)
1	340	380	332	+8	+8
2	340	440	356	-16	-8
3	380	460	364	+16	+8
4	380	520	388	-8	0
5	300	320	308	-8	-8
6	400	520	388	+2	-6
7	280	240	276	+4	-2
8	424	620	428	-4	-6
9	420	600	420	0	-6
10	400	560	404	-4	-10
11	360	440	356	+4	-6
12	320	360	324	-4	-10
13	340	420	348	-8	-18
14	372	480	372	0	-18
15	380	540	396	-16	-34
16	280	280	292	-12	-46
17	280	260	284	-4	-50
18	380	500	380	0	-50

E_{act} - Actual Energy consumption E_{Std} - Standard energy consumption

From the Figure 8.10, it can be seen that the CUSUM graph oscillates around the zero line for several months and then drops sharply after month 11. This suggests that the heat recovery system took almost two months to commission and reach proper operating conditions, after which steady savings have been achieved. Based on the graph 9.10 (see Table 8.4), savings of 44 toe (50-6) have been accumulated in the last 7 months. This represents savings of almost 2% of energy consumption.

CUSUM chart for last 18 months is shown in Figure 9.13.

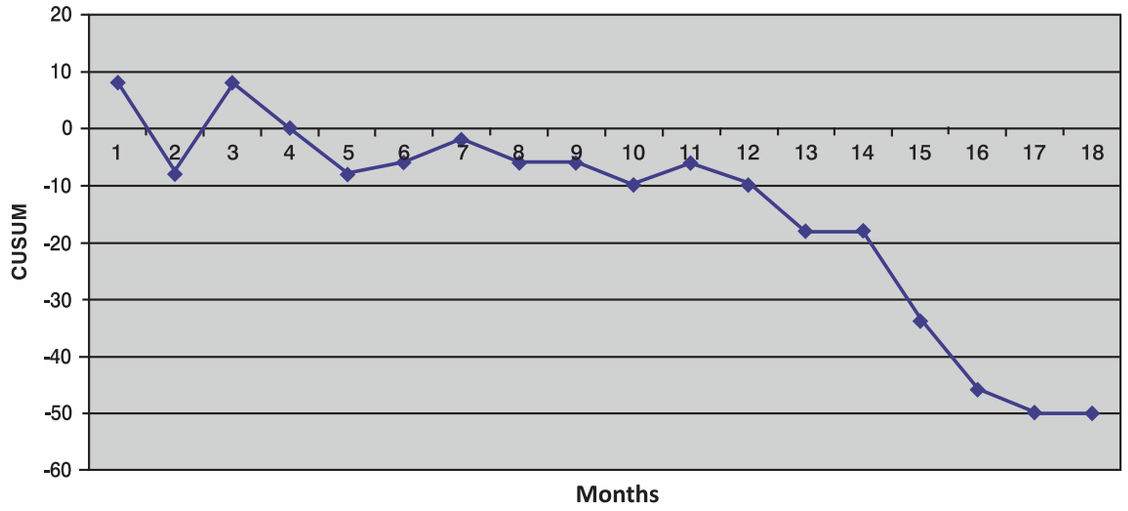

Figure 9.13 Example CUSUM Graph

9.7 Energy Management Information System (EMIS)

The use of specially designed information system software is advisable when operating an M&T programme. Computers should not be seen as a replacement for the energy manager, but simply as tools which enable large amounts of data to be stored and analysed in a short period of time. A number of energy management software packages are commercially available, with varying degrees of complexity. They all tend to share the following generic features:

- ✓ A database facility, which is capable of storing and organizing large quantities of data collected over a long period of time.
- ✓ The ability to record energy data for all utility types, including data taken from both meters and invoices.
- ✓ The ability to handle complex utility tariffs. Tariffs vary from place to place, and are becoming increasingly complex as competition is introduced into the utilities sector.
- ✓ The ability to handle other related variables such as degree days and production data.
- ✓ A data analysis facility. This is achieved by incorporating statistical analysis software into the energy management software.
- ✓ A reporting facility, which is capable of quickly producing energy management reports.
- ✓ With the more sophisticated energy management packages it is possible to interface the software with Building Management Systems (BMS), so that energy data can be automatically recorded on a regular basis (e.g. hourly).

One of the great advantages of computer-based systems is their database facility, which enables historical data and data from many sources to be instantly compared. This facility is particularly useful when comparing site energy costs on a utility basis and enables energy managers quickly to assess the relative performance of various EACs. In this way EACs which are under-performing can be quickly identified and remedial action taken.

Designing Information Reporting Systems

One of the major outputs of any M&T programme is the production of energy management reports. These reports perform the vital role of communicating key information to senior and operational managers, and are therefore the means by which action is initiated within an organization. In order to ensure that prompt action is taken to minimize wasteful practices, reports should be as simple as possible and should highlight those areas in which energy wastage is occurring. Reports should be published regularly so that energy wasteful practices are identified quickly and not allowed to persist for too long. Reports should be succinct, and conform to a standard format which should be generated automatically by a computer. This minimizes preparation time, and also familiarizes managers with the information being communicated.

Most M&T programmes require reports to be published weekly or monthly. Monthly reports are usually applicable to large organizations with many sites, with weekly reports being more suitable to complex high energy consuming facilities. In applications where energy consumption is particularly high, reports may be produced daily. If the reporting period is too long, energy may well be needlessly wasted before managers are notified of the problem and remedial action is taken. Yet, if the reporting period is too short this will lead to an over-complex M&T system in which too much irrelevant information requires consideration.

The primary purpose of energy management reports is to communicate effectively with senior and operational managers. They should therefore be tailored to suit the needs of their readers, with different managers within organizations requiring different levels of report. Operational managers may need weekly reports, whereas senior management may only require a quarterly review. Figure 9.14 illustrates the relationship between reporting frequency and managerial status.

One big disadvantage of producing a large number of regular reports is that they can swamp operational managers with what may appear to be irrelevant information. One good way to get around this problem is to adopt a reporting by exception system, in which reports are only generated when energy performance falls outside certain predetermined limits. This system has the great advantage that managers only receive reports when energy performance is either poor or very good. In addition, everyone involved in the reporting process benefits from a reduced workload.

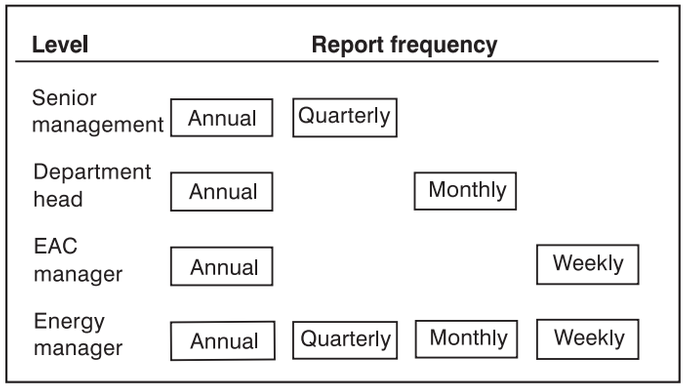

Figure 9.14 Relationships between Managerial Status And Report Frequency

Solved Example:

The Energy- production data (for Jan-June, 2011) of an industry follows a relationship:

Calculated energy consumption = 0.5 P +220.

A Waste heat recovery system was installed at end of June 2011 and further data was gathered up to December 2011.

Using CUSUM technique, calculate energy savings in terms of ton of oil equivalent (toe) and the reduction in specific energy consumption achieved with the installation of waste heat recovery system. The plant data is given in the table below.

2011-Month	Actual Energy Consumption, toe/month	Actual production, ton/month
Jan	620	760
Feb	690	960
Mar	635	790
Apr	628	830
May	545	610
Jun	540	670
July	**590**	**760**
Aug	**605**	**820**
Sep	**670**	**940**
Oct	**582**	**750**
Nov	**512**	**610**
Dec	**540**	**670**

Ans:

The table below gives values of actual energy consumption vs. calculated (predicted) energy consumption from July –Dec. 2011.

Specific energy consumption monitored vs. predicted for each month. The variations are calculated and the Cumulative sum of differences is calculated from Jan-June-2011.

2011-Month	Eact.	Ecal 0.5P+220	Eact - Ecal	CUSUM
July	**590**	600	-10	-10
Aug	**605**	630	-25	-35
Sept	**670**	690	-20	-55
Oct.	**582**	595	-13	-68
Nov.	**512**	525	-13	-81
Dec.	**540**	555	-15	-96

Energy savings achieved = **96 toe**

Reduction in specific energy consumption = 96/4550 = 0.021 toe/tonne of production (Production for 6 months = 760+820+940+750+610+670 = **4550 tonnes**).

QUESTIONS	
Objective Type Questions	
1.	A chart in Scatter Diagram shows a low degree of scatter. It is indicative of------ a) good fit b) poor fit c) skewed fit d) normal fit
2.	Between variables and enables standard equations to be established for energy consumption. a) linear regression analysis b) time-dependent energy analysis c) moving annual total d) CUSUM
3.	In a cumulative sum (CUSUM) chart, if the graph is going up, then a) nothing can be said b) actual and calculated energy consumption are the same c) energy consumption is reduced d) specific energy consumption is going up
4.	Energy monitoring and targeting is built on the principle of " _____". a) "production can be reduced to achieve reduced energy consumption" b) "Consumption of energy is proportional to production rate" c) "You cannot manage what you do not measure" d) None of the above.
5.	Which of the variable does not contribute to energy consumption? a) production b) hours c) climate d) none of the above
6.	Poor scattering on trend line of production Vs Energy consumption indicates _____. a) poor level of control b) good level of control c) both the above d) none of above.
7.	Fixed energy consumption can be determined from a _____ a) bar chart b) vertical line chart c) pie chart d) X Y coordinate system
8.	The best way of correlating production and energy data in any plant is _____ a) text format b) graphical representation c) oral communication d) none
9.	For any company, energy consumption mostly relates to _____ a) profits b) inventory c) production d) all the above
10.	In a cumulative sum chart, if the graph is horizontal, then _____ a) nothing can be said b) energy consumption is reduced c) specific energy consumption is increasing d) actual and calculated energy consumption are the same
Short Type Questions	
S-1	What do you understand by Energy monitoring and targeting?
S-2	What is meant by correlation coefficient? How it is useful in energy monitoring?
S-3	What is the need for a monitoring system?

S-4	List at least 5 steps involved in CUSUM analysis.
S-5	Explain the difference between single variable and multiple variable analysis
	Long Type Questions
L-1	In a food processing plant the monthly production related (variable) energy consumption was 1.8 times the production and non-production related (fixed) energy consumption was 15,000 kWh per month up to May 2010. In the month of June 2010 a series of energy conservation measures were implemented. Use CUMSUM technique to develop a table and calculate energy savings for the subsequent 6 months period from the data given below

Month	Production (kg)	Actual Energy Consumption (kWh)
Jul' 10	62000	113600
Aug' 10	71000	139000
Sep' 10	75000	158000
Oct' 10	59000	119300
Nov' 10	62000	123700
Dec' 10	73000	143600

L-2 Use CUSUM technique and calculate energy savings for first 6 months of 2011 for those energy saving measures implemented by a plant prior to January,2011.
The average production for the period Jan-Jun 2011 is 1000 MT/Month
The plant data is given in the table below.

2011-Month	Actual Specific Energy Consumption, kWh/MT	Predicted Specific Energy Consumption, kWh/MT
Jan	1203	1121
Feb	1187	1278
Mar	1401	1571
Apr	1450	1550
May	1324	1284
Jun	1233	1233

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Chapter 10

Energy Efficiency and Climate Change

Learning Objectives

In this chapter you will learn about

- Linkage between energy and environment
- Global environmental issues
- Impacts of climatic change
- Kyoto protocol and Copenhagen meeting
- Clean development mechanism procedures and steps
- Bachat lamp yojana

10. ENERGY EFFICIENCY AND CLIMATE CHANGE

Energy and environment, Air pollution, Climate change, United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol, Conference of Parties (COP), Clean Development Mechanism (CDM), CDM methodology and procedure, Sustainable development.

10.1 Energy and Environment

The combustion of hydrocarbon based fuels in industrial activity generates by-product materials, many of which are considered to be air pollutants (Figure 10.1). The principal emissions which impact on the air environment are carbon dioxide, particulate matter (dust), sulphur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide.

Figure 10.1 Emissions Due to Energy Use

Particulate matter is predominantly generated during the combustion of solid fuels such as coal, lignite, biomass etc mostly from ash content in the fuel. Sulphur oxide (SOx) emissions mainly occur from combustion of oil and coal due to sulphur content in the fuel. Nitrogen oxides (NOx) emissions are also associated with fuel combustion, both from fuel as well as combustion air. Both SOx and NOx emissions have been identified as major air pollutants globally as they lead to acid rain which is a trans-boundary environmental issue. The main sources of carbon monoxide emissions are due to incomplete combustion of fuels.

Carbon dioxide resulting from the oxidation of carbon in fuels during combustion dominates the total emissions. Although, carbon dioxide is not considered as a pollutant, it is considered as a major contributor to global warming and climatic change.

10.2 Global Environmental Issues

One of the most important characteristics of global environmental issues is that it affects all mankind on a global scale without regard to any particular country or region. These environmental issues have global significance and need to be addressed through international efforts. The whole world is a stakeholder and this raises issues on who should do what to combat environmental problems.

Some of the key environmental issues of global significance are

- ✓ Acid rain
- ✓ Ozone layer depletion
- ✓ Global warming and climatic change
- ✓ Loss of biodiversity

10.3 Acid Rain

Acid rain is caused by release of sulphur oxides and nitrogen oxides from combustion of fossil fuels, which then mix with water vapour in atmosphere to form sulphuric acids and nitric acids respectively (Refer Figure 10.2).

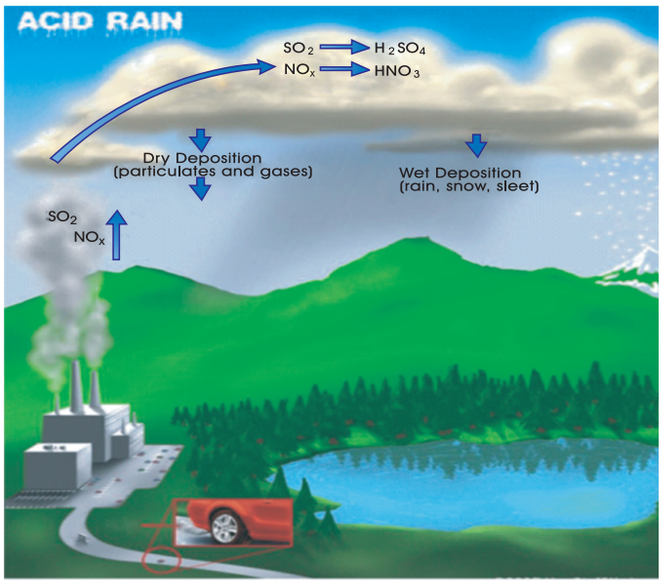

Figure 10.2 Acid Rain Formation

The effects of acid rain are as follows:

- ✓ Acidification of lakes, streams, and soils
- ✓ Direct and indirect effects (release of metals, for example: Aluminum which washes away plant nutrients)
- ✓ Killing of wildlife (trees, crops, aquatic plants, and animals)
- ✓ Decay of building materials and paints, statues, and sculptures
- ✓ Health problems (respiratory, burning- skin and eyes)

10.4 Ozone Layer Depletion

Ozone layer is a thin layer of ozone (O_3) present in stratosphere which extends from 10-50 km from the earth (Figure 10.3). The ozone layer is highly beneficial to life on earth as it blocks the sun's Ultraviolet radiations (UV-B) from reaching the earth. Any disturbance or depletion of ozone layer would result in an increase of harmful radiation reaching the earth's surface leading to dangerous consequences.

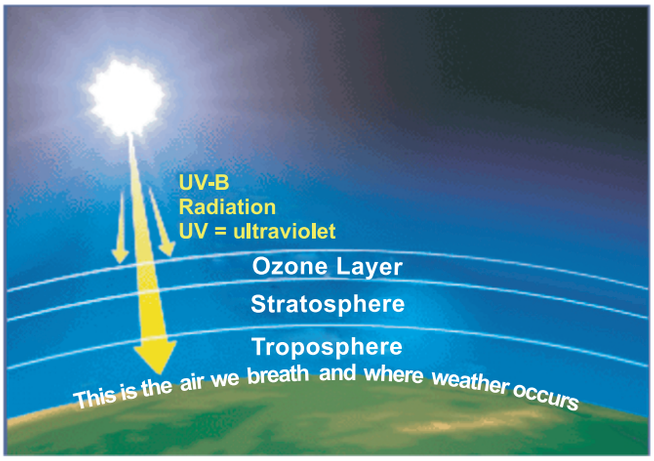

Figure 10.3 Ozone Layer

Ozone, which is highly unstable, is produced and destroyed naturally in the stratosphere and until recently, this resulted in a well-balanced equilibrium (see Figure 10.4). Ozone is formed when oxygen molecules absorb ultraviolet radiation with wavelengths less than 240 nanometres and is destroyed when it absorbs ultraviolet radiation with wavelengths greater than 290 nanometres.

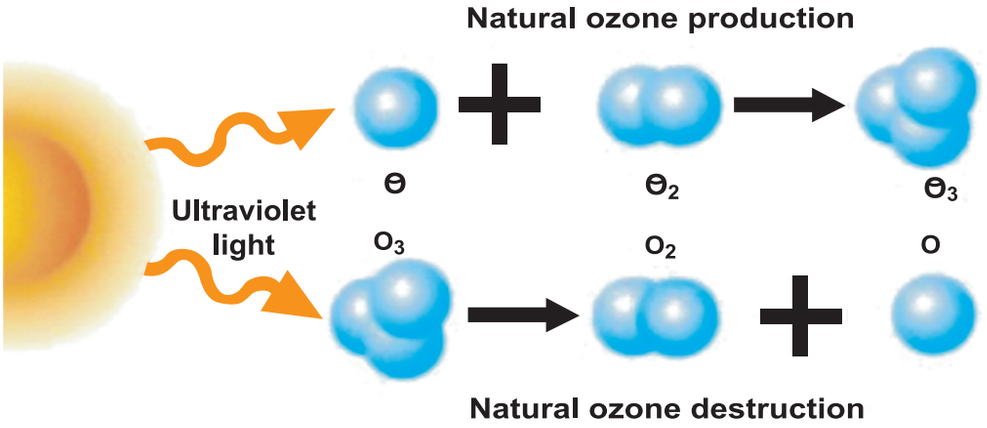

Figure 10.4 Ozone Formation and Destruction

Ozone Depletion Process

In recent years, scientists have measured a seasonal thinning of the ozone layer primarily at the South Pole. This phenomenon is being called the ozone layer depletion. It was found that ozone is easily broken down by man-made chlorine and bromine compounds. These compounds are found to be responsible for most of the ozone layer depletion. The main chemical responsible for the problem is identified as Chloro fluro carbons (CFCs) which were used in refrigerator and air conditioners.

The ozone depletion process begins when Chloro fluro carbons (CFCs) and other ozone-depleting substances (ODS) emitted into the atmosphere reach stratosphere by diffusion. Strong UV radiations break apart the ODS molecules. CFCs, HCFCs, carbon tetrachloride, methyl chloroform release chlorine atoms, and halons and methyl bromide release bromine atoms. It is the chlorine and bromine atom that actually destroys ozone, not the intact ODS molecule. It is estimated that one chlorine atom can destroy from 10,000 to 100,000 ozone molecules before it is finally removed from the stratosphere.

Chemistry of Ozone Depletion

When ultraviolet light waves strike CFC ($CFCl_3$) molecules in the upper atmosphere, a carbon-chlorine bond breaks, producing a chlorine (Cl) atom. The chlorine atom then reacts with an ozone (O_3) molecule breaking it apart and so destroying the ozone. This forms an ordinary oxygen molecule (O_2) and a chlorine monoxide (ClO) molecule. Then a free oxygen atom breaks up the chlorine monoxide, releasing chlorine. The released chlorine is free to repeat the process of destroying more ozone molecules. A single CFC molecule can destroy 100,000 ozone molecules. The chemistry of ozone depletion process is shown in Figure 10.5.

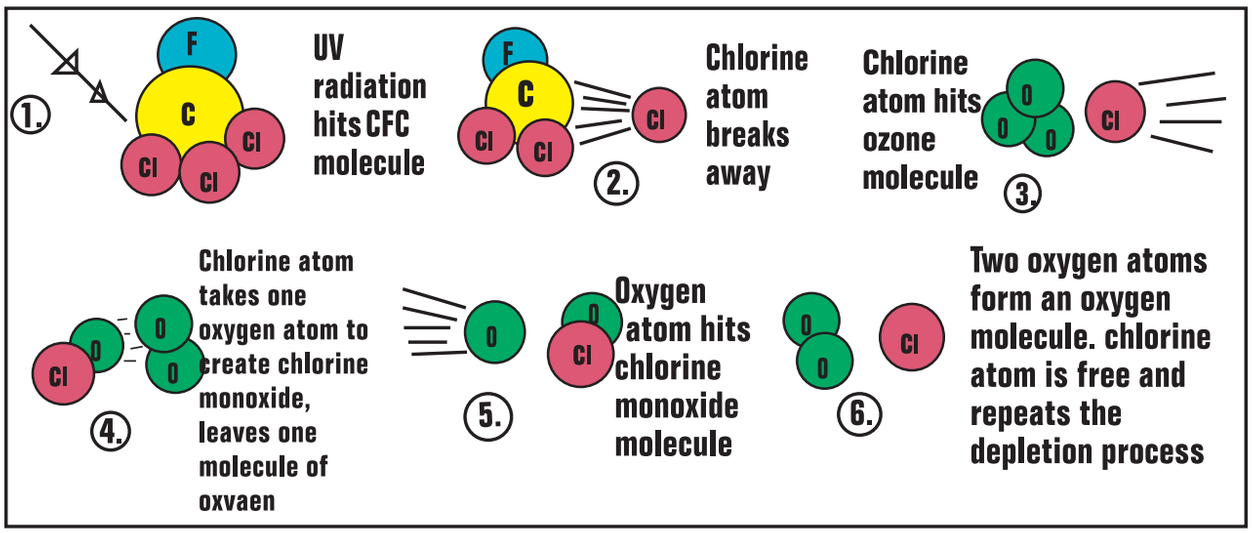

Figure 10.5 Chemistry of Ozone Depletion Process

Effects of Ozone Layer Depletion

Effects on Human and Animal Health: Increased penetration of solar UV-B radiation is likely to have high impact on human health with potential risks of eye diseases, skin cancer and infectious diseases.

Effects on Terrestrial Plants: Increased radiation is likely to change species composition in forest and grassland thus altering the bio-diversity in different ecosystems. It could also affect the plant community indirectly resulting in changes in plant form, secondary metabolism, etc.

Effects on Aquatic Ecosystems: High levels of radiation exposure in tropics and subtropics may affect the distribution of phytoplanktons, which form the foundation of aquatic food webs. It can also cause damage to early development stages of fish, shrimp, crab, amphibians and other animals, the most severe effects being decreased reproductive capacity and impaired larval development.

Effects on Bio-geo-chemical Cycles: Increased solar UV radiation could affect terrestrial and aquatic bio-geo-chemical cycles thus altering both sources and sinks of greenhouse and important trace gases, e.g. carbon dioxide (CO_2), carbon monoxide (CO), carbonyl sulfide (COS), etc. These changes would contribute to biosphere-atmosphere feedbacks responsible for the atmosphere build-up of these greenhouse gases.

Effects on Air Quality: Reduction of stratospheric ozone and increased penetration of UV-B radiation result in higher photo dissociation rates of key trace gases that control the chemical reactivity of the troposphere. This can increase both production and destruction of ozone and related oxidants such as hydrogen peroxide, which are known to have adverse effects on human health, terrestrial plants and outdoor materials.

Ozone Depletion Counter Measures

International cooperation and agreement was signed at Montreal Protocol in 1974 to phase out ozone depleting chemicals. The ozone depletion counter measures include,

- Tax imposed on use of ozone depleting substances
- Use of ozone friendly substitutes- HCFC and HFC (less ozone depleting potential and shorter life)
- Recycle of CFCs and Halons

10.5 Global Warming and Climatic Change

The atmosphere is a thin layer of gas which surrounds the Earth. The two most important layers in the atmosphere are known as the troposphere and the stratosphere. The air layer gets thinner and thinner with altitude. 90% of all the molecules in the atmosphere are in the troposphere.

The atmosphere is composed mainly of 21% Oxygen, 78% Nitrogen, 0.04% carbon dioxide, and Argon 0.04% by volume. In addition, water vapour and several gases are present in very small amounts.

The Greenhouse Effect

The earth is surrounded by a blanket of gases including greenhouse gases. The greenhouse gases are those gases in the atmosphere which by absorbing thermal radiation emitted by the earth's surface have a blanketing effect over the surface keeping it warmer than it would otherwise be. This results in build up of energy, and the overall warming of the atmosphere. This blanket traps energy in the atmosphere, much the same way as glass traps heat inside a greenhouse. Without naturally occurring greenhouse gases such as water vapour, carbon dioxide, methane and nitrous oxide, the earth's average surface temperature would be a cold -18°C rather than the tolerable 15°C. This warming of the earth called the greenhouse effect (Figure 10.6) is a natural process which made life on Earth possible.

The Earth's atmosphere allows short-wave solar radiation from sun to pass relatively unimpeded. The long-wave infrared radiation emitted from the warm earth's surface is partially trapped and re-emitted downwards by greenhouse gases such as water vapour, carbon dioxide, methane, Nitrous oxide, in the upper atmosphere. In this way an energy balance is set up, which ensures that the Earth is warmer than it would be without it.

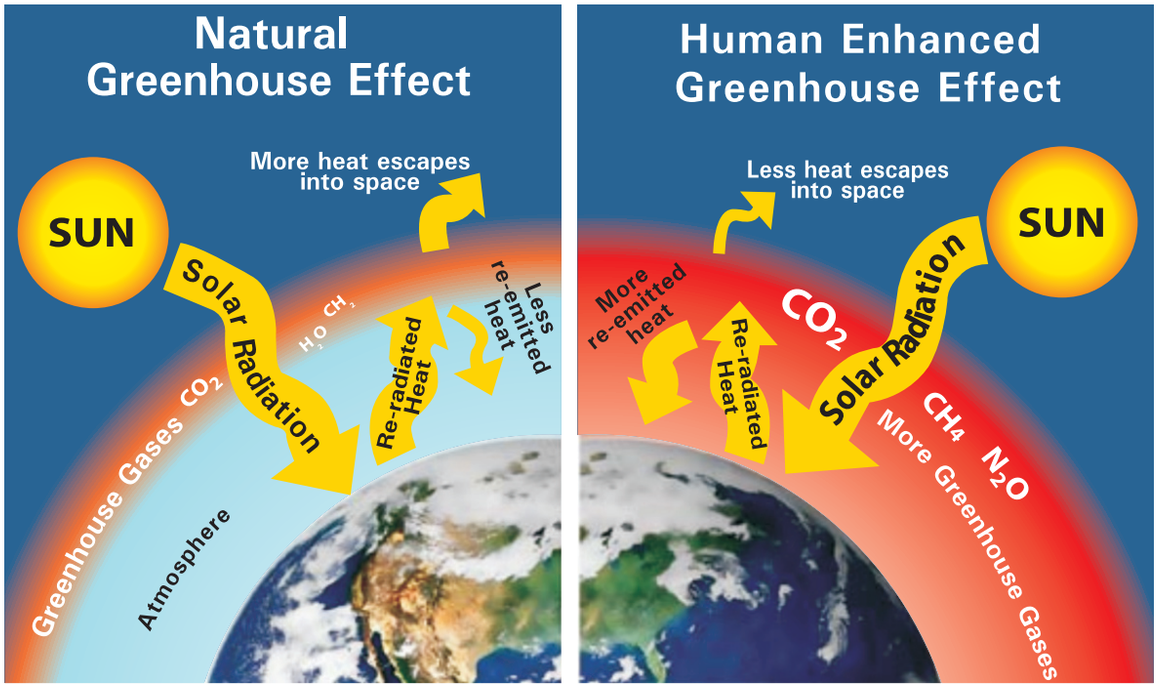

Figure 10.6 Greenhouse Effect

Enhanced Greenhouse Effect

The natural greenhouse effect is enhanced (Figure 10.6) by the increase of greenhouse gases in the atmosphere especially carbon dioxide from burning of fossil fuels, coal, oil and gas, together with wide deforestation over the past 200 years and more substantially over the past 50 years.

Although, water vapour is also considered as greenhouse gas, its amount in the atmosphere is not changing directly because of human activities. The other important greenhouse gases that are directly influenced by human activities leading to enhanced greenhouse effect are carbon dioxide, methane, nitrous oxide, the chlorofluorocarbons (CFCs) and ozone.

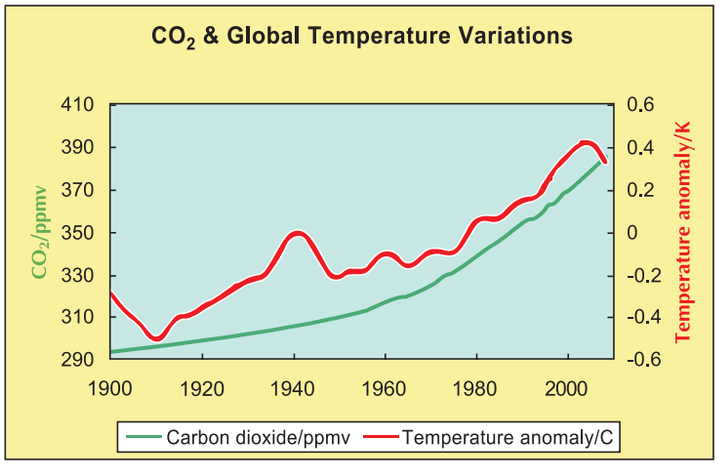

Figure 10.7 Rising Global Temperatures

There is now overwhelming evidence that enhanced greenhouse effect from human activities is changing the global climate. It is estimated that the earth's average temperature has risen by 0.75°C since 1880 because of emissions of greenhouse gases from human activity. The relation between CO_2 and global temperature variations is shown in Figure 10.7.

Greenhouse Gases

Carbon Dioxide: Carbon dioxide is the most important of the greenhouse gases because of its abundance in the atmosphere. The increase in carbon dioxide has contributed to about 60% of the enhanced greenhouse effect as its concentration of 397 ppm (Mauna Loa Observatory: November, 2014 data) is much higher than other greenhouse gases. It is also persistent with atmospheric lifetime of over 100 years.

***Man-made Carbon Dioxide Emissions*:** The major source of CO_2 is fossil-fuel combustion (coal, petroleum, and natural gas). For the same amount of heat released, natural gas emits the least CO_2. Coal-based power plants are the major CO_2 sources in many countries in the world. Among the industrial processes, cement is a major contributor of CO_2 as emissions occur from both fuel combustion and calcination of limestone.

Petroleum-burning motor vehicles are another major contributor of CO_2 emissions. Deforestation contributes too because when felled trees are burned, their stored carbon is released as CO_2. At the same time, deforestation leaves fewer trees to take up atmospheric CO_2.

Carbon Sequestration: It is the term given to the process of removing CO_2 from large point sources such as power plant, oil refineries, industrial process etc. The CO_2 is then stored in geologic formations such as depleted oil and gas reservoirs, deep coal seams or saline reservoirs. Oceans are a major CO_2 sink, containing about 50 times more carbon than the atmosphere. Terrestrial biomass including trees and grasses store about three times more CO_2 than the atmosphere. Together, ocean and terrestrial ecosystems absorb about half the excess CO_2 generated by human activities.

Methane: The main natural source of methane is from wetlands. Methane is also created when organic matter such as food and vegetables decompose without presence of oxygen- a process called anaerobic decomposition.

Anthropogenic sources include leakage during coal mining, leakage from natural gas pipelines and from petroleum wells, rice cultivation, belching from cattle and other livestock, decay of municipal solid wastes dumped in landfill sites and from wood burning.

Methane is a naturally occurring inflammable gas. Methane is produced by geological coal formations and by the decomposition of organic matter. Leading anthropogenic sources of methane are landfills, livestock digestive processes and wastes, especially ruminants (cud-chewing animals) and wetland rice cultivation.

Nitrous Oxide: The emissions to the atmosphere that are associated with human activities are from use of nitrogen fertilizer, manure, biomass combustion, fossil fuel combustion in power plant and the chemical industry (for example. nylon production). Also, N_2O is contained in soil by bacteria. When farmers plow the soil and disturb the surface layer, N_2O is released into the atmosphere. It is also released from catalytic converters in cars. It has an atmospheric lifetime of about 120 years.

Ozone: Ground-level ozone is a greenhouse gas. It can absorb infrared radiation and contribute to warming. Ground-level ozone forms from Volatile Organic Compounds (VOCs) and nitrogen oxides in the presence of heat and the sun's ultraviolet radiation.

Chlorofluorocarbons (CFCs): The CFCs are man-made chemicals which vaporise just below room temperature and are non-toxic and non-flammable. CFC contains chlorine atoms and has been used in industry as refrigerants, cleaning solvents, manufacturing of insulation and propellants in spray cans.

They are so chemically unreactive and once released into the atmosphere, they remain for a long time of about 100 or 200 years before being destroyed.

As an outcome of Montreal Protocol, CFCs are phased out, being replaced by other halocarbons-hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). While HCFC and HFC are less destructive to ozone than the CFCs, they are still considered as greenhouse gases.

Because of their shorter lifetime, and lower concentrations, their contribution to global warming for a given rate of emission, will be less than for the CFCs. However, since their rate of manufacture could increase substantially their potential contribution to global warming is being included alongside other greenhouse gases.

The main sources of Hydroflurocarbons are leakage from refrigeration equipment, release during end of life destruction of equipment, use of HFC containing aerosols, air conditioners etc. These are best contained by recycling the refrigerants.

Perflurocarbons: Perfluorcarbons is also considered as an important greenhouse gas as it has a long atmospheric life, more than several thousand years. All emissions of these gases accumulate in the atmosphere and will continue to influence climate for thousands of years.

Primary aluminum production and semiconductor manufacture are the largest known man-made sources of perfluorocarbons.

Sulphur Hexafluoride (SF_6): Sulfur hexafluoride is the most potent greenhouse gas. It is used in insulation, electric power transmission equipment, the magnesium industry, semiconductor manufacturing to create circuitry patterns on silicon wafers, and as a tracer gas for leak detection.

Global Warming Potential (GWP)

The different types of greenhouse gases all have different properties. For example, the amount of time they reside in the atmosphere and the amount of heat that they trap can vary widely. Many of the greenhouse gases are extremely potent—some greenhouse gases such as sulphur hexafluoride can continue to reside in the atmosphere for thousands of years after they have been emitted.

Some greenhouse gases are 140 to 23,900 times more potent than CO_2 in terms of their ability to trap and hold heat in the atmosphere over a 100-year period. Even though these gases represent a very

small proportion of the atmosphere, their enormous heat-holding potential makes them significant and represents a serious addition to global warming.

In order to understand specific greenhouse gases' potential impact, they are rated on the basis of their global warming potential (GWP). The GWP of a greenhouse gas is the ratio of global warming—or radiative forcing—from one unit mass of a greenhouse gas to that of one unit mass of CO_2 over a period of time, making the GWP a measure of the "potential for global warming per unit mass relative to carbon dioxide." In other words, greenhouse gases are rated on how potent they are compared to CO_2.

GWPs take into account the absorption strength of a molecule and its atmospheric lifetime. Therefore, if methane has a GWP of 23 and carbon has a GWP of 1 (the standard), this means that methane is 23 times more powerful than CO_2 as a greenhouse gas. The higher the GWP value, the larger the infrared absorption and the longer the atmospheric lifetime. As shown in Table10.1, even small amounts of sulfur hexafluoride and HFC-23 can contribute a significant amount to global warming. The increasing concentration of greenhouse gases, GWP and lifetime is given in Table 10.1.

Table 10.1 Increasing Concentration of Atmospheric Greenhouse Gases

Greenhouse gas	Baseline	Current level	GWP	Lifetime in atmosphere (years)
Carbon dioxide (CO_2)	280 ppm	395 ppm	1	5-200
Methane (CH_4)	700 ppb	1893 ppb	23	12
Nitrous oxide (N_2O)	275 ppb	326 ppb	300	114
Ozone	-	-	-	Days/weeks
Chloroflurocarbons (CFC) and related chemicals	0	ppt levels	4000-8000	5-100
Perfluromethane, one of the Perfluorcarbons (PFC)	40 ppt	80 ppt	5700	50000
Sulphur hexafluoride (SF_6)	0.01 ppt	7.79 ppt	22000	3200

Source: Carbon Dioxide Information Analysis Centre (CDIAC) Data
1 ppm = 1g in 1000 kg, 1 ppb = 1 g in 1000 tonnes, 1 ppt = 1 g in 1000 000 tonnes

Global Greenhouse Gas Emissions

Since the Industrial Revolution, annual CO_2 emissions from fuel combustion dramatically increased from near zero to almost 36 Giga tonnes of CO_2 in 2013. Among the many human activities that produce greenhouse gases, the use of energy represents by far the largest source of emissions.

Smaller shares correspond to agriculture, producing mainly CH_4 and N_2O from domestic livestock and rice cultivation, and to industrial processes not related to energy, producing mainly fluorinated gases and N_2O. Within the energy sector, CO_2 resulting from the oxidation of carbon in fuels during combustion dominates the total GHG emissions. CO_2 from fossil fuels & cement contributes almost 70% of global GHG emissions (Figure 10.8).

Figure 10.8 Global CO_2 Emissions (Source: http://co2now.org/)

India's Greenhouse Gas Emissions

India contributed to almost 7% of global emissions and is now third largest contributor in terms of CO_2 emissions behind China and USA. Although, India' emitted about 2.5 Giga tonnes of carbon dioxide in 2013, the per capita emissions is still low at 1.6 tonnes per annum. Coal-based power production, accounted for almost 70% of all of India's coal-related CO_2 emissions.

10.6 Global Warming and Climatic Change Impacts

There is strong evidence now that most of the observed warming over the last 50 years is caused by human activities. Climate models predict that the global temperature will rise by about 6 °C by the year 2100. The major impacts of global warming are as follows:

Increasing Ocean Temperature and Rising Sea Levels

During the twentieth century, observations show that the average sea level increased by about 20 cm. The largest contribution to this rise is from thermal expansion of ocean water as the oceans warm the water expands and the sea level rises. A further increase in average sea level of 10 to 20 cm by 2030 and up to 1 m by 2100 is predicted. The coastal flooding will increasingly occur with rising sea level.

People, who are already poor and overcrowded, may be forced from homes in low-lying countries such as Bangladesh. Even developed countries such as the Netherlands may lose land. Since half of the world populations live near the coastal zones, their vulnerability to rising sea levels are very high.

Snow and Ice Melting

Ice is already melting worldwide, especially at the earth's poles. This includes mountain glaciers, ice sheets covering West Antarctica and Greenland, and Arctic sea ice. Snow and ice melting would also lead to rising sea levels. Also melting ice caps will disturb the ocean ecosystem. Fresh water from melting ice caps would desalinate the oceans and eco systems will be put out of balance and ocean currents which regulate the temperatures will be disturbed. Also cooling property of white ice caps which reflect heat back into space is lost further warming the earth.

Over the past 150 years, the majority of mountain glaciers monitored have been shrinking. Many glaciers at lower latitudes are now disappearing, and scientists predict that the majority of glaciers will be gone by the year 2100. As glaciers continue to shrink, summer water flows will drop sharply, disrupting an important source of water for irrigation and power in many areas that rely on mountain watersheds. Monitoring of Himalayan glaciers indicates that recession of some glaciers has occurred in some regions though not consistently across entire mountain chain.

Altered Rainfall Patterns

Rainfall patterns would be altered, with some areas getting more rainfall and others suffering more droughts. On warmer days, more water evaporates from soil and trees into the air leading to more clouds and rainfall. But moisture can also evaporate from dry soils, depriving them of already limited moisture.

A trend of increasing rainfall has been found along the west coast, northern Andhra Pradesh while decreasing monsoon rainfall trend has been observed over north-eastern India and some parts of Gujarat and Kerala.

Extreme Weather Events

Already, cyclones, storm, hurricanes are occurring more frequently and floods and draughts are more intense than before. This increase in extreme weather events are not considered as random events. Computer models predict this trend towards more powerful storms and hotter, longer dry periods. States of West Bengal, Gujarat and Kerala have reported increasing extreme weather trends.

More Severe Heat Waves

Heat waves and periods of unusually warm weather are already happening and are expected to increase with global warming. Already many cities in India are experiencing increasing heat waves due to global warming.

Temperatures that people from a hotter climate consider normal can be termed a heat wave in a cooler area if they are outside the normal pattern for that area. Severe heat waves have caused catastrophic crop failures, thousands of deaths from heat stroke, and widespread power blackouts due to increased use of air conditioners.

Loss of Biodiversity

Ecosystems will change - some species will move farther north or become more successful; others would not be able to move and could become extinct. Most of the world's endangered species (some 25 per cent of mammals and 12 per cent of birds) may become extinct over the next few decades as warmer conditions alter the forests, wetlands, and rangelands they depend on, and human development blocks them from migrating elsewhere. The oceans, which are source of great biodiversity, would also be affected. For example the coral reefs, which have limited tolerance for warm waters would be severely affected.

Increased Diseases

Diseases currently restricted to existing hot regions may move into the newly warming regions. Malaria is one such disease, spread by mosquito vectors, infecting and killing millions each year in warm climates. As temperature increases in currently temperate regions, mosquitoes and other insects are expected to move in, spreading diseases as they go. In addition, indigenous disease organisms previously killed by winter cold will be better able to survive milder winters.

Dwindling Freshwater Supply

A higher sea level also means salty water can infiltrate fresh groundwater in coastal areas reducing the supply and also making it undrinkable. This is a major concern, since billions of people on earth already lack access to freshwater. Higher ocean levels already are contaminating underground water sources in many parts of the world. Climate change is projected to decrease water availability in many arid- and semi-arid regions. One third of the world's population is now subject to water scarcity

Food Shortages

Food production needs to double to meet the needs of an additional 3 billion people in the next 30 years. Water resources will be affected as precipitation and evaporation patterns change around the world. This will affect agricultural output. Climate change is projected to decrease potential crop yields in the tropics and sub-tropics for almost any amount of warming. Food security is likely to be threatened and some regions are likely to experience food shortages and hunger.

10.7 International Agreements: United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) was signed by over 160 countries at the United Nations Conference on Environment and Development held at Rio de Janeiro in June 1992 came into force from 1994.

It has set the agenda for action to slow and stabilize climate change. The signatories to the Convention recognized the reality of global warming and agreed that action to mitigate the effects of climate change needs to be taken and that developed countries should take the lead in this action.

In 1992 at the UN Earth Summit in Rio de Janeiro, many countries signed this convention. Its objective was to stabilize "greenhouse gas concentrations. at a level that would prevent dangerous anthropogenic interference with the climate system." Anthropogenic interference means human interference.

The Convention mentions a short-term and one far-reaching objective. The short term objective aim is that developed countries should take action to return greenhouse gas emissions, in particular, those of carbon dioxide to their 1990 levels by the year 2000.

The long-term objective of the Convention is that the concentrations of greenhouse gases in the atmosphere should be stabilized 'at a level which would prevent dangerous anthropogenic interference with the climate system', the stabilisation to be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

10.8 The Intergovernmental Panel on Climate Change (IPCC)

The IPCC, the Intergovernmental Panel on Climate Change, was formed in 1988 by the World Meteorological Organization and the United Nations to review climatic data and periodically report on their findings.

Scientists with the Intergovernmental Panel on Climate Change (IPCC) concluded in a 1995 report that the observed increase in global average temperature over the last century "is unlikely to be entirely natural in origin" and that the balance of evidence suggests that there is a "discernible human influence on global climate." Several of their conclusions are summarized below:

- Atmospheric greenhouse gases continue to increase as a result of human activities.
- The fraction of warming due to carbon dioxide exceeds 50%.
- Decreases of about 10% in snow cover have occurred since the late 1960s.
- Reductions in the year's duration of lake and river ice cover occurred in the twentieth century.
- Increases in the heat contained in the world's oceans have occurred since the late 1950s
- Between 0.1 and 0.2 m rise in global average sea levels occurred in the twentieth century.

The panel projects that, if current trends continue, increases in atmospheric greenhouse gases in the twenty-first century will result in an average global temperature increase between 1.4 and 5.8◦C. About 75% of the warming is expected to be due specifically to carbon dioxide. They also project sea-level rises of another 0.1 to 0.9 m.

The 1995 IPCC report greatly altered the world's view of climate change, and led to the 1997 Kyoto Protocol, an international agreement among industrialized nations to modestly reduce emissions of greenhouse gases.

10.9 Conference of Parties (COP)

The COP is the "supreme body" of the Convention. The Parties to the United Nations Framework Convention on Climate Change (UNFCCC) meet annually in form of COP. The primary task is to promote and review the implementation of the Convention and any related legal instruments (such as the Kyoto Protocol, etc.). Countries that have joined the UNFCCC are referred to as "Parties to the Convention". The meetings held between each COP are known as Intersessional meetings.

The landmark COP is COP 3 which resulted in Kyoto Protocol in 1997. The Kyoto Protocol includes legally binding emission targets for developed countries (Annex I Parties) for the six major greenhouse gases, which are to be reached by the period 2008-2012.

10.10 The Kyoto Protocol

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change. The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions. This amounts to an average of five per cent against 1990 levels over the five-year period 2008-2012.

The major difference between the Protocol and the Convention is that while the convention encouraged industrialized countries to stabilize GHG emissions, the protocol commits them to do so.

Recognizing that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier responsibility on developed nations under the principle of "common but differentiated responsibilities."

The Kyoto Protocol entered into force on 2005 when Russia signed the protocol. All the participating countries have ratified the protocol other than United States. USA which contributes to almost 25% of global greenhouse gases has not yet ratified the protocol citing reasons that protocol has failed to include binding targets and timetables for developing countries such as China and India and that US economy would be seriously harmed.

Kyoto Protocol Reductions

Parties to the Kyoto Protocol wanted flexibility in how they could pursue reductions in greenhouse gas emissions. They spent great amounts of time discussing flexibility mechanisms, ways by which a

nation could take credit for reducing emissions. Flexibility mechanisms are intended to supplement not replace direct actions by a country or company such as conserving fossil fuel.

Targets

The targets cover emissions of the six main greenhouse gases, namely:

- ✓ Carbon dioxide (CO_2)
- ✓ Methane (CH_4)
- ✓ Nitrous oxide (N_2O)
- ✓ Hydrofluorocarbons (HFCs)
- ✓ Perfluorocarbons (PFCs)
- ✓ Sulphur hexafluoride (SF_6)

The maximum amount of emissions (measured as the equivalent in carbon dioxide, CO_2e) that a Party may emit over the commitment period in order to comply with its emissions target is known as a Party's assigned amount. The individual targets for Annex I Parties as per Kyoto Protocol are listed in Table 10.2.

Table 10.2 Emission Targets for Countries listed in Kyoto Protocol

Country	Target (1990** - 2008/2012)
EU-15*, Bulgaria, Czech Republic, Estonia, Latvia,Liechtenstein, Lithuania, Monaco, Romania, Slovakia, Slovenia, Switzerland	-8%
US***	-7%
Canada, Hungary, Japan, Poland	-6%
Croatia	-5%
New Zealand, Russian Federation, Ukraine	0
Norway	+1%
Australia	+8%

* The 15 States who were EU members in 1990 will redistribute their targets among themselves, taking advantage of a scheme under the Protocol known as a "bubble", whereby countries have different individual targets, but which combined make an overall target for that group of countries. The EU has already reached agreement on how its targets will be redistributed.

** Some EITs (Economies In Transition) have a baseline other than 1990.

*** The US has indicated its intention not to ratify the Kyoto Protocol.

Parties

The Convention divides countries into three main groups according to commitments:

Annex I Parties include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

Annex II Parties consist of the OECD members of Annex I, but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change. In addition, they have to "take all practicable steps" to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries.

Non-Annex I Parties are mostly developing countries. Developing countries are recognized by the Convention as being especially vulnerable to the adverse impacts of climate change, including countries with low-lying coastal areas and those prone to desertification and drought. Others (such as countries that rely heavily on income from fossil fuel production and commerce) feel more vulnerable to the potential economic impacts of climate change response measures. Needs and concerns are addressed through investment, insurance and technology transfer.

The Kyoto Protocol Mechanisms

Parties with commitments under the Kyoto Protocol have accepted targets for limiting or reducing greenhouse gas emissions. These targets are expressed as levels of allowed emissions, or "assigned amounts," over the 2008-2012 commitment periods.

Under the Treaty, countries must meet their targets mainly through national measures. The Kyoto Protocol also offers them an additional means of meeting their targets by way of three market-based mechanisms. The Kyoto mechanisms are:

- Emissions trading – also known as "the carbon trading"
- Clean development mechanism (CDM)
- Joint implementation (JI).

The mechanisms help stimulate green investment as well as help Parties meet their emission targets economically.

Emission Trading

Emissions trading allow countries that have emission units to spare - emissions permitted to them but not "used" - to sell this excess capacity to countries that are over their targets. Emission trading is also

known as carbon trading since carbon dioxide is the principal greenhouse gas. Carbon is now tracked and traded like any other commodity. This is known as the "carbon market."

Clean Development Mechanism (CDM)

The Clean Development Mechanism (CDM) allows a country with an emission-reduction under the Kyoto Protocol to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto Protocol targets. The mechanism results in sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction or limitation targets. The major CDM projects have been from renewable energy followed by waste handling and disposals.

Joint Implementation (JI)

The mechanism known as "joint implementation," allows a country with an emission reduction under the Kyoto Protocol to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex I country, each equivalent to one tonne of CO_2, which can be counted towards meeting its Kyoto target. A JI project must provide a reduction in emissions by sources, or an enhancement of removals by sinks, that is additional to what would otherwise have occurred. Joint implementation offers Parties a flexible and economic means of fulfilling a part of their Kyoto commitments, while the host Party benefits from foreign investment and technology transfer.

The difference between JI-projects and CDM-projects is that JI-projects are done between countries that both have commitments, while the CDM-projects is between one country that has commitments and another country that does not have commitments. Emissions reductions that have been done through CDM-projects during the period 2000 to 2007 can be used for fulfilling commitments in Annex I countries for the period 2008-2012.

10.11 CDM Methodology and Procedure

Project Cycle for CDM

The various stages of the project cycle for CDM are shown in Figure 10.9. Of these, last three stages are performed throughout the life cycle of the project.

Project Preparation: The first step in the CDM project cycle is the identification and formulation of potential CDM Projects. This can be done by comparing potential projects against the list of already approved methodologies available with UNFCCC. This step establishes that the CDM project is real, measurable and additional.

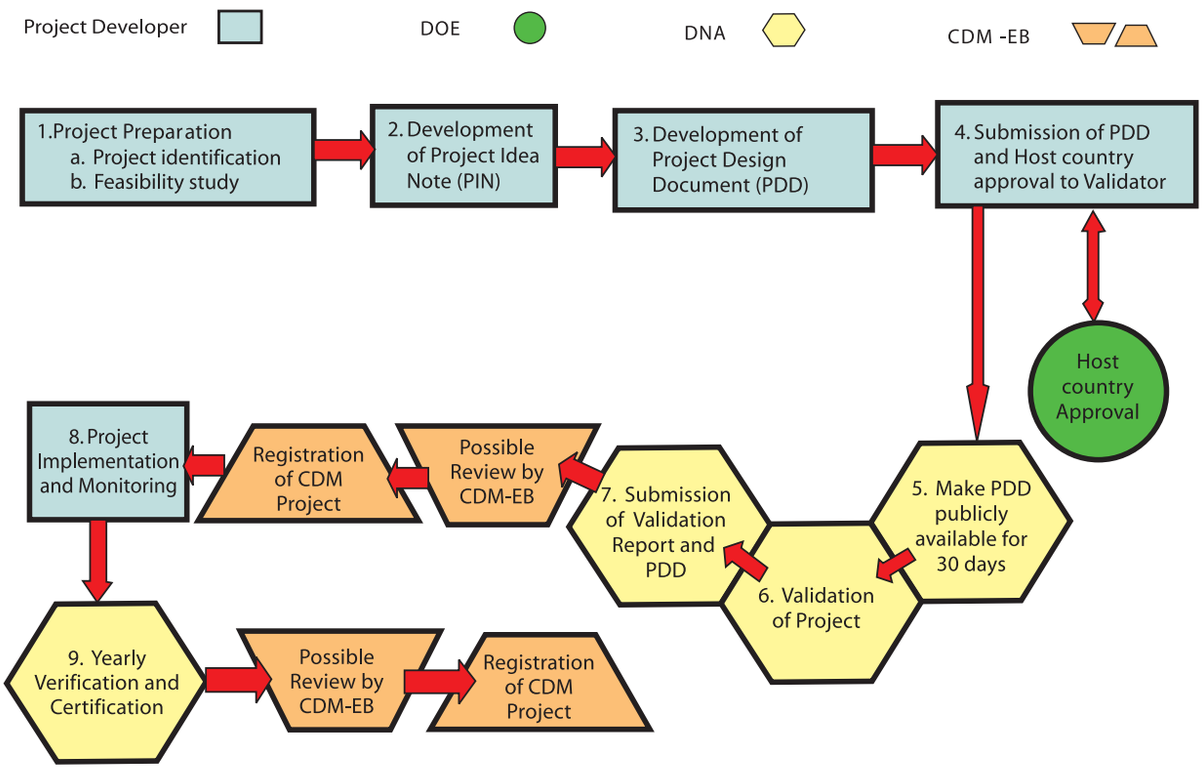

Figure 10.9 CDM Project Cycle

Potential CDM projects include,

- Zero emission renewables – grid-connected electricity generation for renewable sources.
- Biomass – grid-connected electricity from biomass.
- Waste – landfill gas project activities.
- Animal waste – change of animal waste management activities.
- Cement – increasing the blend in cement production.
- Energy efficiency
- Small scale CDM projects include type 1 (renewable energy), type II (energy efficiency improvements), and type III (other projects)

Small-scale projects for fast track CDM approval

Certain small-scale projects may be eligible for CDM fast track approval. Reasons for introducing a "fast track" for small-scale projects are:

- CDM process too costly for small projects through normal process (high transaction costs);
- Many small projects deliver significant local sustainable development benefits;
- Small-scale technologies are some of the most promising for solving the long term problem of climate change (e.g. solar; wind; fuel cells);
- CDM might lose public support if rules are biased toward large capital-intensive projects.

There exist three small-scale project types:

- Type I: renewable energy projects with a capacity of up to 15 MW
- Type II: energy efficiency projects which reduce the energy consumption on the demand and supply side by up to 15 GW/year (54 TJ) in comparison to the business-as-usual scenario
- Type III: other projects which reduce emissions and are emitting less than 15 kT CO_2/year

The CDM project developer is advised to carry out a technical and economic feasibility study of the project. This is not a requirement for the CDM project application, but it helps to prove the additionality of the project and gives clear information of Return on Investment with and without CDM. Depending on what the feasibility study covers, it can also facilitate the preparation of the Project Idea Note and the Project Design Document.

Development of Project Idea Note (PIN): If the results of the pre-screen and feasibility study are positive, the developer and/or their advisors should develop a Project Idea Note, or PIN. Although a PIN is not required for CDM application, it helps to inform the Designated National Authority (DNA) of the host country about the project and obtain feedback about the country's specific sustainability requirements. The PIN also can be used to get feedback from potential carbon credit buyers in the marketplace about their level of interest, prior to going through the entire CDM process. The PIN will subsequently be screened by the recipient entities against the CDM rules and their investment criteria.

A PIN consists of approximately five pages providing indicative information on:

- Type and size of the project;
- Location of the project;
- Anticipated total amount of GHG reduction compared to the 'business-as-usual' scenario (which will be explored further in the Project Design Document);
- Suggested crediting life time;
- Suggested CER price (in US$/$tCO_2$ equivalent reduced)
- Financial structuring (indicating which parties are expected to finance the project; and
- Project's other socio-economic or environmental effects/ benefits.

Development of Project Design Document: The PDD is the key document in the CDM cycle. The PDD is mandatory and is submitted to a Designated Operational Entity (DOE) for validation, and subsequently to the CDM Executive Board for registration before CERs are issued.

The baseline methodology and the baseline scenario are essential elements of PDD as these are used to calculate the amount of CER's that are generated by the project. The baseline methodology outlines how baseline emissions are determined and baseline scenario determines the actual emissions before project implementation. Project proponents can either use an existing methodology to calculate the baseline for this kind of projects or choose to develop a new methodology.

Another central issue in CDM projects is from when, and for how long, the project will generate CER (also known as the crediting period). For almost all CDM projects, carbon credits are counted from the date that the project starts, and resulting in GHG emission reduction. For some rare CDM projects where CDM project had already started and been registered only afterwards, carbon credits are counted only from the date of registration as a CDM project.

Project Design Document

A. General description of the project
B. Setting of the baseline
C. Duration of the project / Crediting period
D. Setting of the monitoring plan
E. Estimation of GHG emission reductions
F. Environmental impacts
G. Stakeholders' comments

Annex 1: Contact information on participants

Annex 2: Information regarding Public Funding

Annex 2: Baseline information

Annex 3: Monitoring plan

The second question is for how long the project will be considered to generate CER. In principle this is for as long as the project fulfills the CDM requirements (and most importantly among these, that there are no new and more attractive technologies or projects that could replace the project on commercial grounds and generate even less GHG). This could become a very complicated issue to prove, and to make things easier, projects can either be valid for one period of ten years only, or for up to three periods of seven years each, but with revalidation of the project every seventh year.

The completed PDD along with the required reports has to be submitted to the DNA in the host country for approval. Host country approval of CDM projects is essential to ensure that governments retain sovereignty over their natural resources and their ability to mitigate emissions. The DNA's responsibility is to review and approve the proposed project under CDM and to confirm whether the project meets the host country's sustainable development criteria.

Host Country Approval: The National CDM Authority in the non-Annex I nation evaluates and approves the project and serves as a point of contact. Together with the investor, the host country developer must prepare a Project Design Document (PDD). National CDM Authority in India is Ministry of Environment & Forest (MoE&F)

Validation / Registration of Project: The PDD and host country approval documents are submitted to an accredited DOE for review and validation. The DOE initiates the validation process by making PDD publicly available for comments by parties, stakeholders and UNFCCC accredited observers for 30 days. After 30 days, DOE prepares a report with verbal and written comments explaining how the comments have been responded. Subsequently, the DOE undertakes a validation process of the CDM project.

- This involves evaluating the PDD and associated documents against the requirements for CDM to confirm that all the information and assumptions made are accurate and reasonable.
- Validation occurs at the outset of a project and is distinct from verification, which occurs during the operation of the project.

Finally, the DOE submits the PDD, host country approval, and validation report to the CDM-Executive Board for registration of the project. It is recommended that the project developer requests the DOE for a copy or confirmation of the request for registration.

Registration of the project with the CDM Executive Board is the act of formal acceptance of the validated project. The registration of the project with the Executive Board will be final after a maximum of eight weeks after submission, unless the CDM EB decides to request a review.

Once the project has been registered, it can be implemented. However, since CERs can also accrue from the point of validation, certain projects are implemented prior to registration.

Project Implementation and Monitoring: Carbon funds are available through

- International tenders for CDM projects
- Voluntary corporate initiatives
- Multilateral Funds
- EU commitments for carbon purchase
- Bilateral negotiations with the consortium of buyers

The public funding for CDM projects must not result in the diversion of funds for official development assistance (ODA). The CERs generated by CDM projects will be subject to 2% levy, to help particularly vulnerable developing countries adapt to the adverse effects of climate change.

Once the project is operational, the project participants have to monitor the project's performance according to the procedures laid out in the validated monitoring plan of the PDD. Monitoring report is prepared including an estimate of CERs generated.

Monitoring is not a one time activity. It is continued for the entire duration of crediting period (7 years x 3 or 10 years). At the very minimum, technical project performance has to be monitored, including project output and related GHG emissions, environmental impact and leakage. The leakages are indirect emissions increases or decrease outside the defined the project boundaries such as changed consumer behaviour or reduced transport.

Verification: Verification is the periodic review and ex-post determination of the monitored GHG emission reductions that have occurred as a result of the CDM project. The DOE verifies that the data collected by the developer are accurate and complete and have been collected in accordance with the monitoring plan. Verified GHG emission reductions from the CDM project form the basis for CERs. CERs are based on actual reductions during the specific time period for which the monitoring results are provided, which is usually one year.

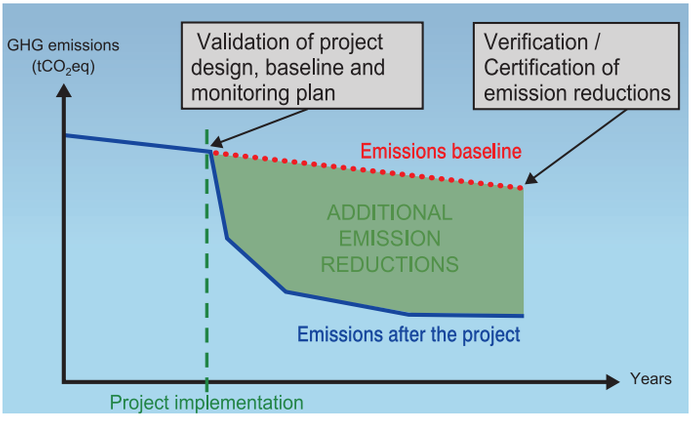

Figure 10.10. Additional Emission Reduction

An operational entity will verify that the CERs have resulted according to the guidelines and conditions agreed upon during the initial validation of the project. Subsequently, verification is carried out on an annual basis through the selected DOE. Refer Figure 10.10.

Certification and Issuance of CER: The operational entity provides a certification report that gives written assurance that a project achieved the reduction as verified. Unless a project participant or three Executive Board members request a review within 15 days, the CERs are issued.

However, current demand for CERs is low. A number of Annex I countries are not participating in the Kyoto Protocol or its second commitment period. In addition, approximately two-thirds of the present quantitative limit set by the European Union Emissions Trading System for the use of emission reduction units (ERUs) and CERs has already been used. Therefore currently confirmed demand is not nearly sufficient to accommodate the current supply capacities of the mechanism.

Requests for issuance have also declined though less significantly, primarily because the marginal cost of requesting issuance is relatively low in comparison with the costs of developing, implementing, and registering a project. Nevertheless, rates of issuance requests are well below the peak levels of 2011 and 2012 and may be expected to remain low in light of the current demand levels.

10.12 European Union's Efforts to Combat Climate Change

The 2020 Climate and Energy Package (EU)

The climate and energy package is a set of binding legislation which aims to ensure the European Union meets its ambitious climate and energy targets for 2020.

These targets, known as the "20-20-20" targets, set three key objectives for 2020:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20%;
- A 20% improvement in the EU's energy efficiency.

The 20-20-20 targets represent an integrated approach to climate and energy policy that aims to combat climate change, increase the EU's energy security and strengthen its competitiveness. These targets were set by EU leaders in March 2007, when they committed Europe to become a highly energy-efficient, low carbon economy, and were enacted through the climate and energy package in 2009.

The EU Emissions Trading System (EU ETS)

The EU emissions trading system (EU ETS) is a policy tool evolved by European Union to combat climatic change by reducing industrial greenhouse gas emissions cost-effectively. The EU ETS covers more than 11,000 power stations and industrial plants in 31 countries, as well as airlines.

A 'Cap and Trade' System

The EU ETS works on the 'cap and trade' principle. A 'cap', or limit, is set on the total amount of certain greenhouse gases that can be emitted by the factories, power plants and other installations in the system. The cap is reduced over time so that total emissions fall.

Within the cap, companies receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of allowances available ensures that they have a value.

After each year a company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company that is short of allowances. The flexibility that trading brings ensures that emissions are cut where it costs least to do so.

In 2020, emissions from sectors covered by the EU ETS will be 21% lower than in 2005. By 2030, the Commission proposes, they would be 43% lower.

10.13 Sustainable Development

According to the Bruntland Commission Report "Our Common Future" presented in 1987, sustainable development is 'meeting the needs of the present without compromising the ability of future generations to meet their own needs'.

A more detailed definition:

'Sustainable development means living on the Earth's income rather than eroding its capital' and 'keeping the consumption of renewable natural resources within the limits of their replenishment'

It recognizes the intrinsic value of the natural world explaining that sustainable development 'means handing down to successive generations' not only manmade wealth (such as buildings, roads and railways) but also natural wealth, such as clean and adequate water supplies, good arable land, a wealth of wildlife and ample forests'.

Sustainable development encompasses three basic and inter-related objectives:

- Economic security and prosperity
- Social development and advancement
- Environmental sustainability

Sustainable development demands that we seek ways of living, working and being that enable all people of the world to lead healthy, fulfilling, and economically secure lives without destroying the environment and without endangering the future welfare of people and the planet.

Sustainable development as applied to energy and environment should consider the following:

- Inputs - such as fuels and energy sources, land and raw materials - are non-renewable they should be used up only as far as they can be substituted in future
- Where they are renewable they should be used up at a rate within which they can be renewed,
- Outputs - in production and consumption - should not overstrain ecosystems or the assimilation capacity of the ecosphere.

QUESTIONS	
Objective Type Questions	
1.	The Global Warming Potential (GWP) of sulfur hexafluoride is a) 1 b) 23 c) 300 d) 22,000
2.	Global warming will not result in a) melting of the ice caps b) increasing sea levels c) increasing the size of the hole in the ozone layer d) unpredictable climate patterns
3.	The ozone layer found in the stratosphere: a) protects against the sun's harmful UV rays b) can react with atmospheric pollutants to form smog c) is toxic to plants d) is capable of disintegrating fabric and rubber on earth
4.	The main constituent of greenhouse gases (GHG) in atmosphere is a) CO2 b) SOx c) nitrogen d) water vapour
5.	The Global Warming Potential (GWP) of nitrous oxide (N2O) is a) 1 b) 23 c) 300 d) 5700
6..	Which of the following is not an environmental issue of global significance? a) ozone layer depletion b) global Warning c) loss of Biodiversity d) suspended particulate Matter
7.	Which among the following has the lowest Global Warming Potential? a) Perflurocarbon b) chloroflurocarbons c) methane d) nitrous oxide
8.	The depletion of Ozone layer is caused mainly by _____ a) nitrous oxide b) carbon dioxide c) choloroflourocarbons d) methane
9.	Which of the following statements regarding responsibility of climate change mitigation is correct? a) industrialized countries bare the sole responsibility in climate change mitigation because they are responsible for most of the GHG emitted to date due to their economic growth b) developing countries bare the sole responsibility as they will be responsible for most of the GHG emission increase in the future due to their population growth c) both industrialized and developing countries share the equal responsibility as a member of the international community d) both industrialized and developing countries share common responsibility but taking into account the respective capabilities towards mitigation
10.	The process of capturing CO2 from point sources and storing them is called _____. a) carbon sequestration b) carbon sink c) carbon capture d) carbon adsorption

Short Type Questions	
S-1	A renovation and modernization (R&M) program of a 110 MW coal-fired thermal power plant was carried out to enhance the operating efficiency from 28% to 32%. The specific coal consumption was 0.7 kg/kWh before R&M. For 7000 hours of operation per year and assuming the coal quality remains the same, calculate a) the coal savings per year and b) the expected avoidance of CO2 into the atmosphere in Tons/year if the emission factor is 1.53 kg CO2/kg coal
S-2	Explain the linkage between energy and environmental issues with examples
S-3	Explain the significance of GWP?
S-4	List four impacts of global warming
S-5	Explain what do you mean by biodiversity
Long Type Questions	
L-1	Explain green house effect and enhanced green house effect?
L-2	Explain COPs, purpose and its implications for developed and developing countries?

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Chapter 11

New and Renewable Energy Sources (NRES)

Learning Objectives

In this chapter you will learn about

- Solar energy terminology
- Solar flat plate collector and evacuated tube collector
- Solar power tower and parabolic trough collector
- Solar PV system
- Components of wind turbine
- Biomass, bio-energy, bio-fuels and bio-gas
- Fuel cell basics
- Energy from wastes
- Tidal energy
- Geothermal energy

11. NEW AND RENEWABLE ENERGY SOURCES (NRES)

Concept of renewable energy, Solar energy, Wind energy, Biomass energy (biomass combustion, biogasification, biomethanation and biofuels), Hydro energy, Fuel cells, Energy from wastes, Wave, Tidal and Geothermal energy

11.1 Concept of New and Renewable Energy

Renewable energy is energy obtained from sources that are essentially inexhaustible such as sun and wind. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power, bio-energy (bio-fuels grown sustainably) and hydropower. A renewable energy system converts the energy found in sunlight, wind, falling-water, sea-waves, geothermal heat, or biomass into a form, we can use such as heat or electricity. Another important feature of renewable energy is that it can be used without the release of harmful pollutants. Renewable energy is also known as non-conventional energy. Renewable energy sources are essentially flows of energy unlike the fossil and nuclear fuels which are considered stocks of energy.

11.2 Fundamentals of Solar Energy

Solar radiation is radiant energy emitted by the sun comprising of ultra-violet, visible and infra-red radiation. The amount of solar radiation that reaches any given location is dependent on several factors including the geographic location, time of day, season, landscape, and local weather.

Because the earth is round, the sun strikes the surface at different angles ranging from 0º (just above the horizon) to 90º (directly overhead). When the sun's rays are vertical, the earth's surface gets maximum energy possible. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse.

Solar Constant

Solar constant is the rate at which solar energy, at all wavelengths, is received per unit area at the top level of Earth's atmosphere. The solar constant actually varies by about 0.3% over the 11-year solar cycle but averages about 1,368 W/m^2. Each planet has its own planetary solar constant.

Solar Insolation

Solar Insolation is the amount of solar energy that strikes a square metre of the earth's surface in a single day. Insolation is greatest when the surface is normal to the Sun. As the angle increases beyond a direction normal to the surface and the sunlight, the insolation is reduced in proportion to the cosine of the angle. The average incoming radiation is known as solar insolation and is one-fourth the solar constant, or 342 W/^{2}.

Solar Window is the period, typically 9 AM - 3 PM, when maximum sunlight is available.

By knowing the insolation levels of a particular area, required size of solar collector and energy output can be calculated. An area with poor insolation levels will need a larger collector than an area with high insolation levels. The values are generally expressed in kWh/m^2/day. India receives solar energy in the region of 5 to 7 kWh/m^2 for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plant per square kilometre land area.

Solar energy can be used through two different routes, namely, Solar Thermal Energy and Solar Electric (Solar Photovoltaic) Energy. Solar thermal systems uses the sun's heat and convert it into heat energy while solar photovoltaic systems uses sun's heat to produce electricity.

11.3 Solar Thermal Energy

Solar collectors are the main component of most of solar energy systems. The collector absorbs the sun's energy and converts it into heat energy. This energy is then transferred to a fluid or air which is used to heat water, generate electricity, dry materials, distill water or cook food. When used for heating purpose, solar thermal system can partially or fully replace the conventional fuels such as coal, oil and electricity.

Various applications of solar thermal energy discussed are

- **Solar Water Heating System** *(Flat-plate collector & Evacuated tube collector)*
- **Solar Thermal Power Systems** *(Power tower, parabolic trough collector)*

Solar Water Heating System

A solar water heating system (Figure 11.1) consists of a flat plate or evacuated tube solar collector, a storage tank and connecting pipes. The system is generally installed on the roof or on open ground, with the collector facing the sun and connected to a continuous water supply. The collectors are generally mounted on a north-facing roof (in southern hemisphere). Water stored in the tank remains hot overnight as the storage tank is insulated and heat losses are small.

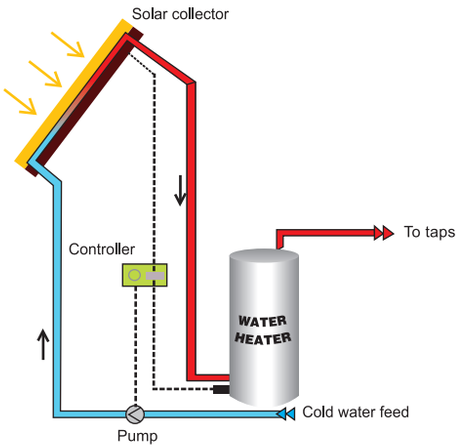


Figure 11.1 Solar Water Heating System

Solar Flat Plate Collector

The most common collector is called a flat-plate collector. Flat-plate collectors heat the circulating fluid to a temperature of about 40-60°C. Flat plate collector is highly dependent upon ambient temperatures. It has good efficiency if ambient temperature is high. Consequently, heat output is higher during summer months than winter months in a flat plate collector.

The flat plate collector (Figure 11.2) usually comprises of copper tubes welded to copper sheets (both coated with a highly absorbing black coatings) with toughened glass sheet on top for cover and insulating material at the bottom. The entire assembly is placed in a flat box.

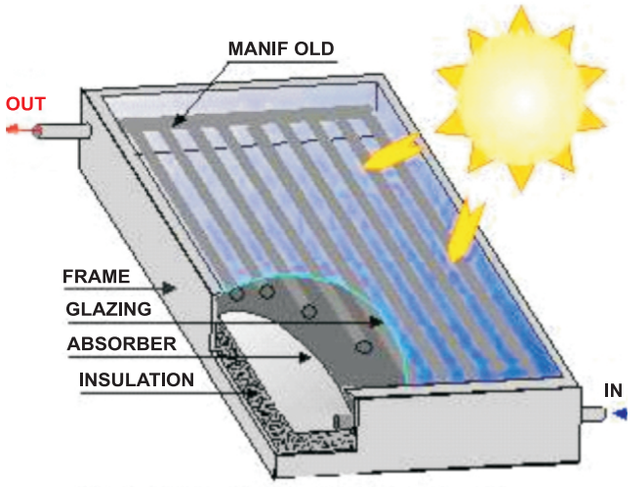


Figure 11.2 Solar Flat Plate Collector

Evacuated Tube Collector

For higher temperatures, evacuated tube collectors are used. Evacuated tube collector is less dependent upon ambient temperature unlike flat plate collector and its efficiency does not drop with ambient temperature.

In this type of solar collector, evacuated glass tubes are used instead of copper in which case a separate cover sheet and insulating box are not required. Water flows through the tubes, absorbs solar heat and is stored in a tank. This type of solar collector can reach high temperatures upto 150°C. Evacuated tube collector is shown in Figure 11.3.

Figure 11.3 Evacuated Tube Collector

Evacuated tube collector comprises of two concentric glass tubes fused in the ends as shown in Figure 11.4. The air is evacuated from the gap between the tubes. The evacuated double-walled glass tube provides thermal insulation similar to that of thermally insulated "Thermos" bottle. The outer glass tube is clear, and the surface of the inner glass tube is coated with a special heat material that absorbs the sun's energy.

Sun rays penetrate the outer clear glass and heat energy is absorbed by the inner coated glass. The vacuum permits the heat radiation to enter the outer tube. The absorbent coating on the inner tube converts short wave radiation to long wave radiation thus preventing re-radiation to atmosphere. Since conduction cannot take place in vacuum, heat loss due to conduction back to atmosphere is also prevented. Because of this principle, more heat is trapped compared to a flat plate collector. The heat loss in Evacuated tube collector is less than 10% compared with 40% for a flat plate collector. Water flows in through a third, innermost concentric feeder tube and hot water flows out in the annulus outside the feeder tube in contact with the absorber tube surface.

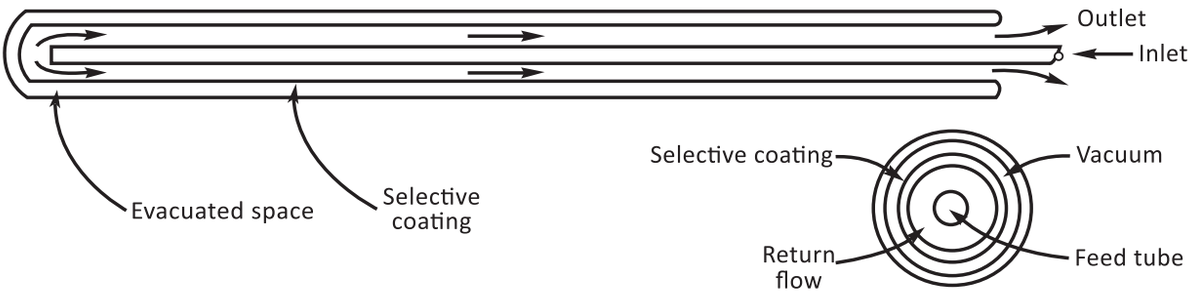


Figure 11.4 Cut view of Evacuated Tube Collector

11.4 Solar Electrical Energy

There are broadly two ways of generating electrical energy from solar power; the thermal route and direct conversion route through photovoltaic. There are two basic types of solar thermal power stations: power tower and parabolic trough collector.

Power Towers

A typical power tower (see Figure 11.5) operation is described as follows:

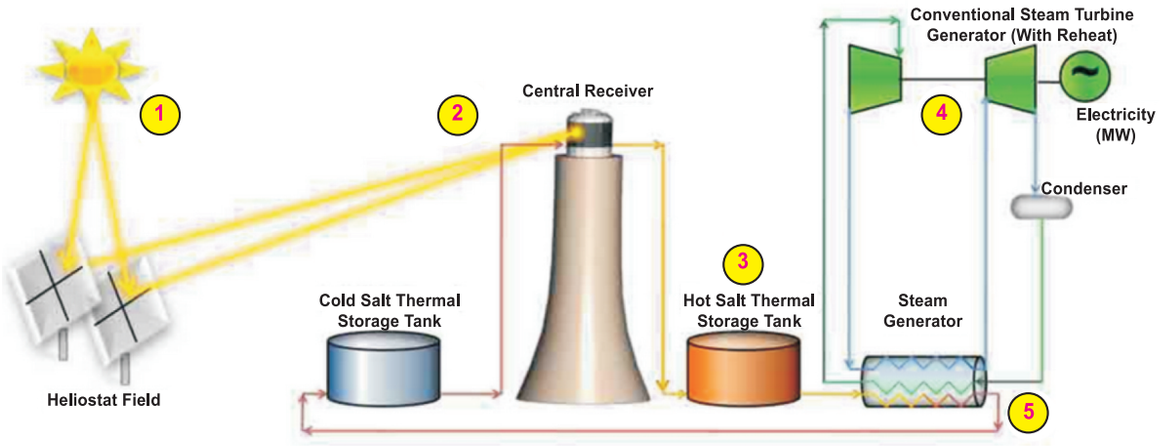


Figure 11.5 Solar Thermal Power Stations

1. Sunlight is concentrated and directed from a large field of heliostats (mirrors) to a receiver on a tall tower.
2. Molten salt (for example liquid sodium) from the cold salt tank is pumped through the central receiver where it is heated to 566°C).
3. The heated salt from the receiver is stored in the hot salt thermal storage tank.
4. Molten salt is pumped from the hot salt tank through a steam generator that creates steam, which drives a steam turbine, generating electricity.
5. Cold salt at 288°C flows back to the cold salt thermal storage tank and is re-used.

Molten salt is a mixture of 60% sodium nitrate and 40% potassium nitrate. It is preferred as it provides an efficient low-cost medium to store thermal energy and it is non-flamable and nontoxic.

Parabolic Trough Collector

Parabolic Trough Collector is currently the most proven solar thermal electric technology. This system uses a series of specially designed parabolic curved, trough shaped reflectors that focus the sun's energy onto a receiver tube running at the focus of the reflector as shown in Figure 11.6. Because of their parabolic shape, troughs can focus the sun at 30-60 times its normal intensity on the receiver pipe. Heat transfer fluid (such as water) in the receiver is heated to a temperature of about 400^{o}C.

Large arrays of these collectors are coupled to provide high temperature water for driving a steam turbine. The collectors are aligned on an east-west axis and the troughs are rotated to follow the sun to maximize the sun's energy input to the receiver tube. Such power stations can produce many megawatts (MW) of electricity, but are confined to areas where there is sufficient solar insolation.

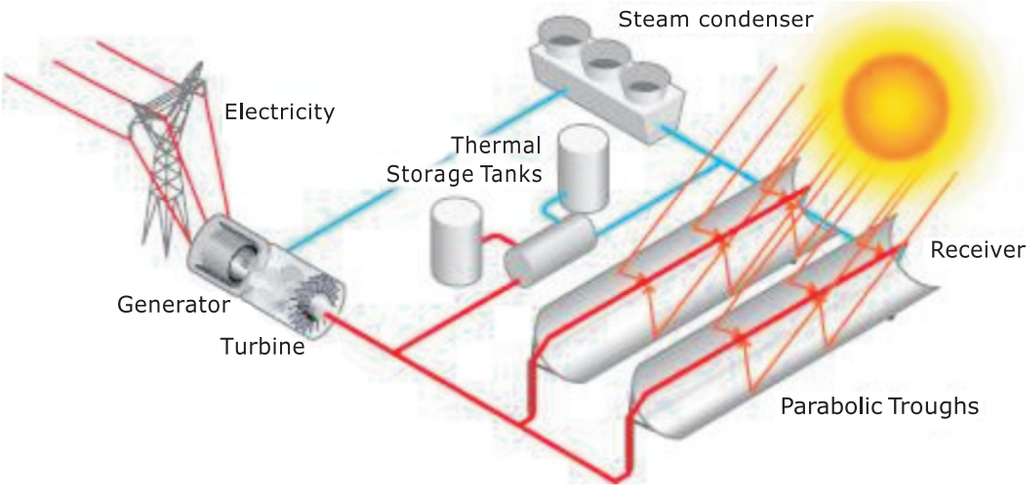


Figure 11.6 Parabolic Trough Collector

Solar Photovoltaic Technology

Direct conversion of solar energy to electricity takes place through photoelectric effect. The photoelectric or photovoltaic effect is the process in which the two dissimilar materials in close contact produce an electrical voltage when struck by light or radiant energy. Discrete packets of light energy known as photons, strike the Photovoltaic (PV) cell, knocking the electrons in the silicon material out of their normal energy state, putting them in a position to be conducted as electricity (Refer Figure 11.7).

The photoelectric effect only occurs when a photon which has the correct amount of energy strikes an atom in the solar cell. The amount of energy needed is dependent on the material the solar cell is made from. This means that the solar cell is not able to convert all the different wavelengths of light which are hitting it. Because of this, solar cells are "tuned" during their manufacturing to absorb the spectrum of sunlight that is most intense. This phenomenon is exploited to form the individual solar cells on wafers of silicon. Since Silicon is naturally reflective in nature, each photovoltaic cell is typically covered with an anti-reflective coating to minimize any loss from reflection.

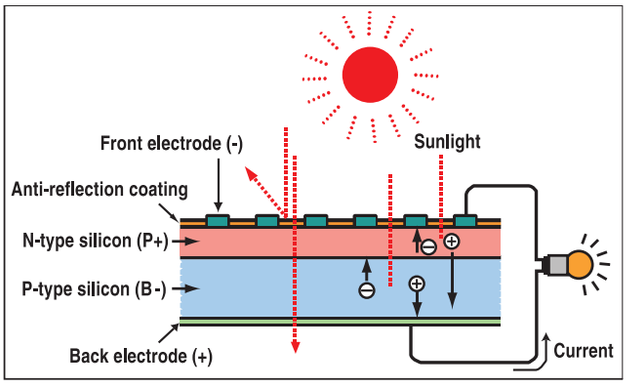


Figure 11.7 Solar Photovoltaic Effect

PV panels comprise of PV cells. Solar cells are connected in series and parallel combinations to form modules that provide the required power. PV cells have been made with silicon (Si), gallium arsenide (GaAs), copper indium diselenide (CIS), cadmium telluride (CdTe), and a few other materials.

A Photovoltaic (PV) module comprise of PV panels (also known as solar panels), battery system, charge controller, inverter as shown in Figure 11.8.

One silicon cell generally produces 0.5 Volts. 36 such cells connected together are called a PV module and it has enough voltage to charge 12 V battery and run pump and motor. Modules can be connected together to form an array and generate more power.

The wattage output of a PV module is rated in terms of peak Watt (Wp). The peak Watt output power from a module is defined as the maximum power output that the module could deliver under standard test conditions. Single PV module can be manufactured with capacity ranging from 5 Wp to 120 Wp.

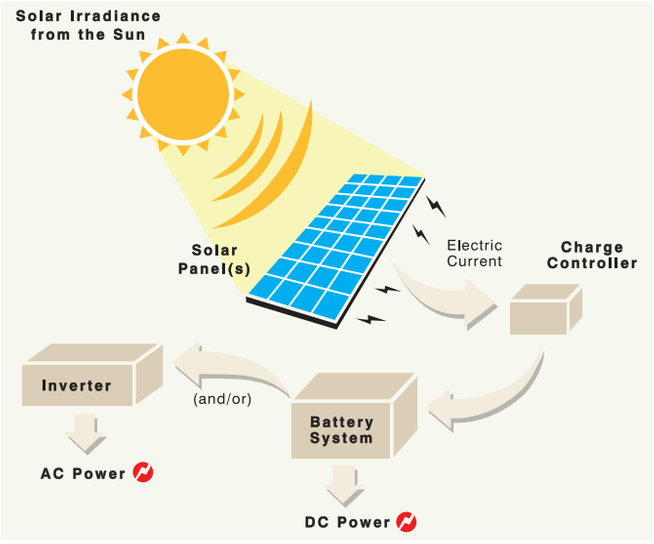


Figure 11.8 PV System

Stand-alone SPV Power Plant: These systems are used where conventional grid supply is not available, or is irregular. In an SPV power plant, electricity is centrally generated and made available to users through a local grid in a 'stand-alone mode'. The most common use for such plants is the electrification of remote villages, power for hospitals, hotels, communication equipment, railway stations, border outposts etc.

Grid connected Solar System: Grid connected solar system (Figure 11.9) use an inverter that synchronizes with the utility power. These systems do not generally require batteries, although batteries can be used to provide backup power if the utility power goes out. Grid connected solar is easier to install and maintain than stand-alone system.

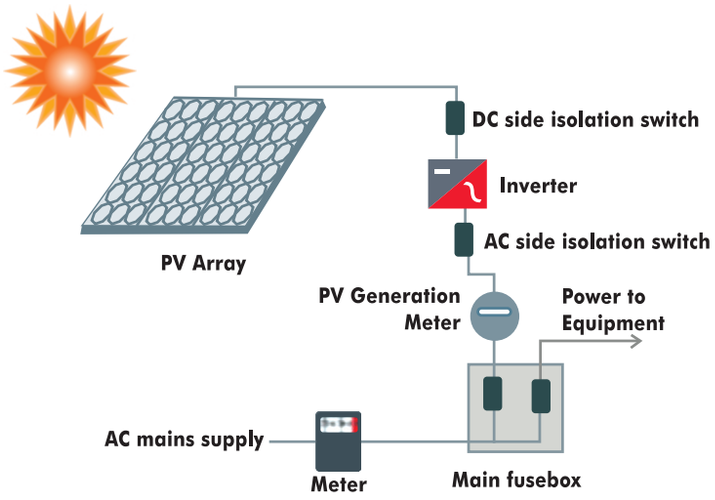


Figure 11.9 Grid Connected Solar

How much of Solar Energy is converted into Electrical Energy in Photovoltaic Cells?

The energy conversion efficiency is a measure of how much of the solar energy is converted into electrical energy. The calculation for the energy conversion factor is,

$$\eta = (Pm / (E * A)) * 100$$

Where,

η = Energy conversion factor, percent.
Pm = Maximum power output, watts.
E = Solar energy, insolation, watts per square meter.
A = Area of the solar cell, square meters.

For example, what is the energy conversion efficiency of a 175-watt solar panel that measures 0.75 x 1.50 meters, if the solar insolation is 1,000 W/m^2?

Since the area of the solar cell is 0.75 * 1.50 = 1.125 m^2, the efficiency is,

$\eta = (175 / (1.125 * 1,000)) * 100$
$\eta = 15.6\%$.

This particular unit converts 15.6% of the available solar energy into electrical energy.

Building-integrated PV Systems: In building-integrated photovoltaic (BIPV) system, PV panels are integrated into the roof or façade of a building as shown in Figure 11.10. BIPV provides photovoltaic power as well as weather proofing and glazing of buildings. SPV panels generate electricity during the daytime, which is used to meet a part of the electrical energy needs of the building. Since PV cells are integrated into the buildings, no separate costly mountings are required.

Figure 11.10 BIPV

11.5 Wind Energy

The use of wind energy is not new and has been used for thousand of years for applications such as water pumping, milling grains, mechanical power, sailing etc. However, it is the use of wind energy for electricity generation that is receiving most attention today. Modern windmills are normally called as wind turbines as their functions are similar to gas and steam turbines. They are also called as wind energy conversion systems (WECS), and those used to generate electricity are described as wind generators.

How Wind is Created?

As the earth orbits the sun daily, it receives light and heat. The majority of the heat from the sun is received at the equator and it gradually reduces towards both poles. Across the earth these heat differences help create wind. In warmer regions of the earth the air is hot and is therefore at a high pressure, compared to colder regions, where the air is at a low pressure. Wind is the movement of air from area's of high pressure to low pressure. Ideally, wind should flow from equator to the direction of either pole if earth is not rotating.

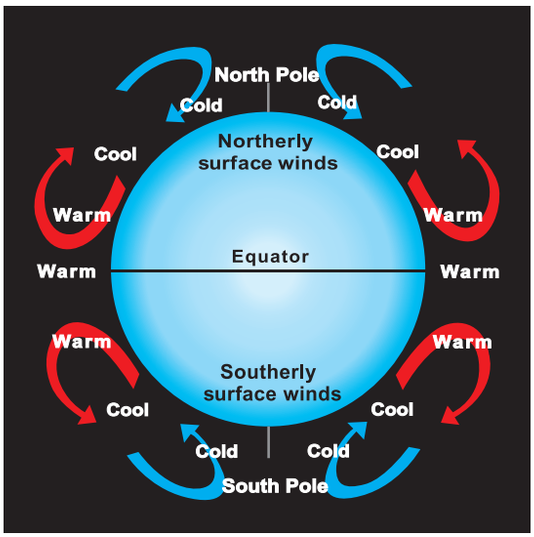


Figure 11.11 Global Wind Flow

However, rotation of earth creates a force known as Coriolis force. The Coriolis force is swirling action on the winds because of earth rotation. This causes series of wind circulations in both northern and southern latitude as shown in Figure 11.11.

The local winds are largely affected by earth terrain. The earth has large flat plains (desert regions), areas covered with plant life (rainforests), very uneven regions (mountain ranges) and very smooth regions (seas and oceans), all of which affect the wind near the surface of the earth to varying levels. Sea breeze is set up when hot air rises from land, which is heated faster than sea, rises into the sky where it cools off. High in the sky, the cooled air now moves towards the sea and sinks pressing cold air from sea towards land.

Variability in Wind Speed and its Effect

Wind speed and direction are continuously fluctuating. The wind will vary over few hours with weather system. Generally, tropics have steady moderate winds all year, temperate latitudes have much more variation in wind speed and in particular more high wind speed occurrences. Sites with more wind speed will generate more power. The Table 11.1 gives a guideline of different wind speeds and their potential in producing electricity.

Table 11.1 Wind Speed vs Power Generation Suitability

Average Wind Speed m/s (km/h)	Suitability for Power generation
Upto 4 (15)	No good
5 (18)	Poor
6 (22)	Moderate
7 (25)	Good
8 (29)	Excellent

Description of Wind Energy Technology

The most common type is horizontal-axis machines. Horizontal-axis wind turbines have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind.

Blades on rotor of horizontal-axis machines can be in the front (upwind) or behind (downwind) of the tower.

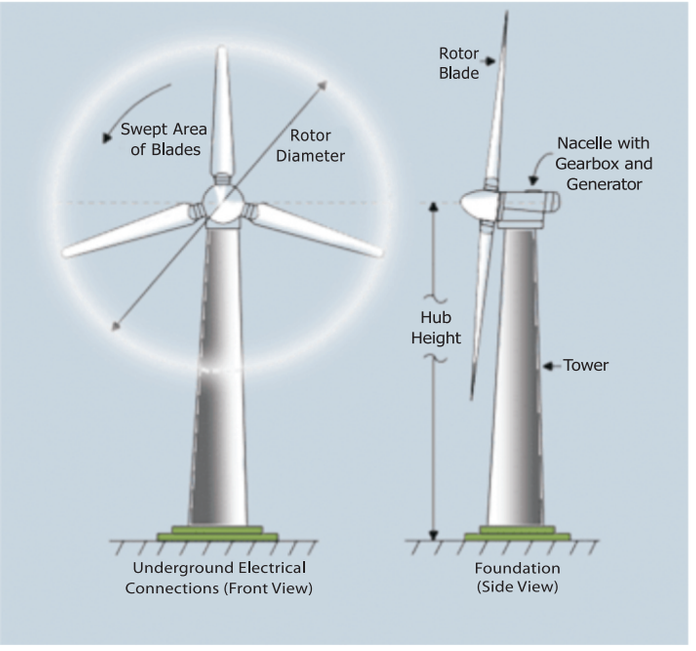


Figure 11.12 Rotor and Blades

Components of wind turbine system

The various components of a wind turbine system are shown in the Figure 11.12 and detailed description is given as follows:

Rotor: The shape of rotor blade and angle in relation to the relative wind direction affect the aerodynamic performance of the blades. Rotors can be single bladed, two-bladed or three-bladed. Multi-bladed rotors are also available. Two- and three-bladed rotors are commonly used for power generation. The three-bladed rotors operate more smoothly and generally more quietly than two-bladed rotors. Multi-bladed rotors have large starting torque in light winds and are used for water pumping and low frequency mechanical power.

Nacelle Assembly: Nacelle is the part of wind turbine at top of tower housing containing gear box, generator assemblies and any control component. The main components of Nacelle assembly are shown in Figure 11.13.

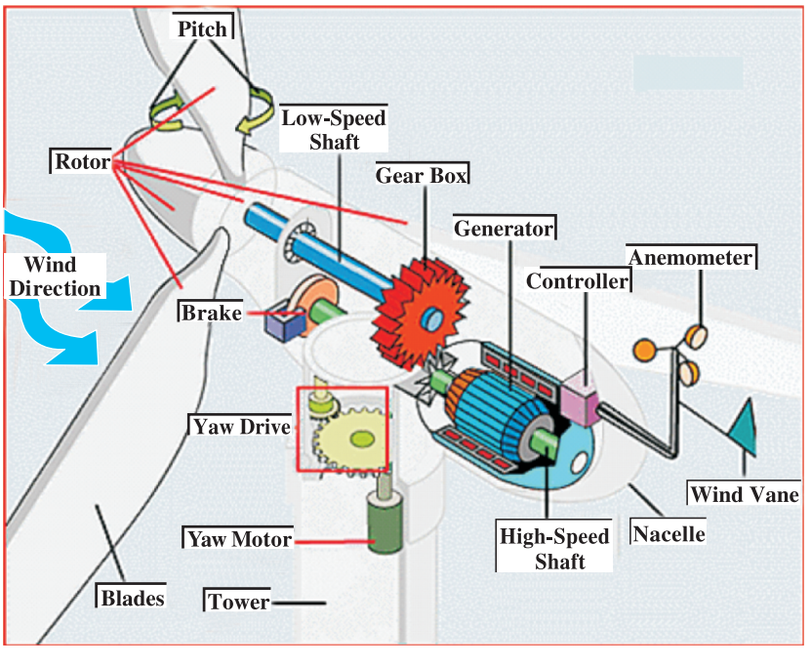


Figure 11.13 Nacelle Assembly

Low-speed shaft: The low-speed shaft, which is the main shaft, is connected directly to the rotor hub. The rotor turns the low-speed shaft at about 30 to 60 rotations per minute.

High-speed shaft: The high-speed shaft is connected to the low-speed shaft by the gear box and drives the generator. The high-speed shaft will turn at between 1,000 and 1,800 rpm.

Gear box: Gears connect the low-speed shaft to the high-speed shaft and increase the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1,000 to 1,800 rpm, which is the rotational speed required by most generators to produce electricity.

Generator: The generator converts the turning motion of wind turbines blades into electricity. For commercial applications, the most common type of generator is an induction generator that produces 50-cycle AC electricity.

Disc Brake: The disc brake is located on main shaft before the gear box or on high speed shaft after the gear box. The basic purpose is to slow down the rotor.

Yaw Control: It is necessary for rotor axis to be aligned with wind direction in order to extract as much of wind kinetic energy as possible. Large wind turbines with upwind rotors require yaw control to align the rotor with the wind. To enable this, any change in wind direction, sensors activate the yaw control motor, which rotates the nacelle and rotor assembly until turbine is properly aligned.

Operating Characteristics of Wind Turbine

A few of the important operating characteristics of a wind turbine include the cut-in speed, rated speed, cut-out speeds, power output and capacity factor. Refer Figure 11.14.

Cut-in Speed: There is a minimum speed at which a wind turbine can reliably produce useable power. This is known as the cut-in speed which is generally around 5 m/s.

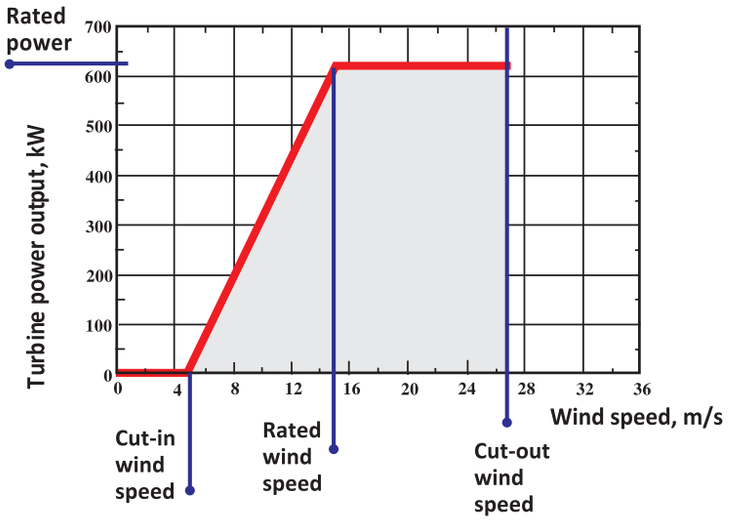


Figure 11.14 Idealised Power Curve for a Wind Turbine

Rated Speed: Most wind turbines are designed to generate maximum power at a fixed wind speed. This is known as rated power and the minimum wind speed at which it is achieved is the rated wind speed. The rated wind speed is chosen to fit the local site and wind regime and is often 1.5 times the site mean wind speed.

Cut-out Speed (Furling Speed): Above a certain speed beyond the rated speed, the wind turbine will need to shut down and stop operation to prevent damage to the unit. Cut-out speeds vary by manufacturer from about 20 to 30 m/s. The wind speed at which shut down occurs is called the cut-out speed. Cut-out speed is also known as furling speed.

Betz Limit: It is impossible for the blades of a wind turbine to be 100% efficient since some of the wind energy must pass through the blades to make the turbine turn. Air flowing over the blades and through the rotor area makes a wind turbine function. The wind turbine extracts energy by slowing down the wind. The theoretical maximum amount of energy in the wind that can be collected by a wind turbines rotor is approximately 59%. This value is known as the Betz limit. Considering the Betz limit and the efficiency losses through the generator, gearbox, etc, will result in only about 15-25% of the wind energy being converted into useful power.

Rotor Efficiency: The ability of a turbine rotor to extract the wind's power depends upon its "efficiency". Thus to express the power output of the turbine, a non-dimensional coefficient of performance of the blades (Cp) is included.

The coefficient of performance of blades (Cp) varies with speed and generally varies between 0.33 -0.59.

Power Available from the wind turbine: Power extracted by wind turbine is proportional to the cross sectional area of the wind intercepted by wind turbine and cube of the wind speed.

The power generated by a wind turbine can be found using the following formula:

Kinetic Energy from the wind = ½ * Mass * Velocity^2

$$\textbf{Mass} = \rho * A * V$$

$$P = 0.5 * \rho * A * Cp * Ng * Nb * V^3$$

Where,

P = Power produced by the generator, watts
ρ is air density in kg/m^3
A is cross sectional area of the wind intercepted by the wind turbine, m^2
Cp = Coefficient of performance of the blades
Ng = Generator efficiency
Nb = Gearbox efficiency
V is wind speed in metres/sec

Power generated is highly dependent upon wind speed. Doubling the wind speed increases the power by eight times, but doubling the turbine area only doubles the power. Thus optimizing the siting of wind turbines in the highest wind speed areas has significant benefit and critical for the best economic performance.

For example, consider a wind turbine with 6 m diameter rotor, a coefficient of performance of 0.30, generator efficiency of 0.8, a gearbox efficiency of 0.90, and a wind speed of 11 m/s.

What is the expected power output in watts?

$P = 0.5 * 1.2 * 3.14/4 * 6^2 * 0.30 * 0.8 * 0.9 * 11^3$

P = 4875 watts, or 4.875 kW

Capacity Factor: The capacity factor of a wind turbine is the actual energy output of a wind turbine during a given time period, usually one year, compared to its theoretical maximum energy output.

The capacity factor (CF) is,

CF = kWh produced / (8760 * Nameplate rating of the wind turbine, kW)

Typical capacity factors are 20-40% with values at the upper end of the range in particularly favorable sites.

A 2.5 MW wind turbine could produce theoretical maximum of 21,900,000 kWh's per year (2.5 * 1,000 *8760).

However, due to the variability of the wind the unit has actually produced 5,000,000 kWh per year.

In this example, the capacity factor is,

CF = 5,000,000 / (2.5 * 1,000 *8760)

CF = 22.8%

11.6 Biomass Energy

Biomass is basically organic matter such as wood, straw, crops, algae, sewage sludge, animal waste and/or other biological waste. Bioenergy is the energy derived from biomass. In energy terms, biomass can be viewed as a form of stored solar energy. The sun's energy is captured and stored (via photosynthesis) in the biomass material. The carbon dioxide released during the burning of biomass when used as fuel is largely balanced by the absorption/ capture of carbon dioxide during its growth. Hence it is considered *'carbon neutral'*

The different methods used to generate energy from biomass are:

Direct Combustion of Biomass

Biomass energy used to generate heat and electricity through direct combustion in modern devices, ranging from very small scale domestic boiler to multi megawatt size power plant electricity.

Direct combustion is the combustion of biomass in a grate, stoker or fluidized bed with excess air followed by capturing the release of energy, which can then be used to provide steam or hot water for process heating and/or for providing electricity. Solid biomasses include coconut shells, rice husks, bagasse, wood waste, oil seed cakes such as de-oiled bran (DOB) etc. Biomasses of low bulk density are processed into pellets or briquettes. A typical pelleted fuel is shown in Figure 11.15.

Figure 11.15 Pelleted Fuel

Gasification of Biomass

Biomass contains carbon, hydrogen and oxygen molecules. Complete combustion would produce carbon dioxide (CO_2) and water vapour (H_2O) whereas combustion under controlled conditions i.e. partial combustion produces carbon monoxide (CO) and hydrogen (H_2), which

are combustible gases. The biogas produced through gasification is called as producer gas. The producer gas has relatively low calorific value, ranging from 1000 to 1200 kcal / Nm^3. The conversion efficiency of the gasification process is the range of 60-70%. It can be used for combustion in a reciprocating engine. When gas is used in dual fuel DG set, it can result in 65-85% diesel savings.

Gasification is a partial combustion of biomass and takes place at temperature of about 1000°C. Partial combustion is facilitated by supplying air less than stoichiometric requirements. The products of combustion are combustible gases like Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4) and non useful products like tar and dust. The production of these gases is by reaction of water vapor and carbon dioxide through a glowing layer of charcoal. Thus, the key to gasifier design is to create conditions such that (a) biomass is reduced to charcoal and, (b) charcoal is converted at suitable temperature to produce CO and H_2.

A gasification system consists of four main stages:

- ✓ Feeding of feedstock
- ✓ Gasifier reactions where gasification takes place
- ✓ Cleaning of resultant gas
- ✓ Utilization of cleaned gas.

Biomass gasifier (Figure 11.16) is a thermo chemical converter / reactor where various physical and chemical reactions take place. Biomass is passed through various zones – Drying/ Distillation Zone, Pyrolysis Zone, Combustion Zone & Reduction Zone. When the biomass is passed through all the above zones, it gets converted into a high quality combustible gas called Producer Gas.

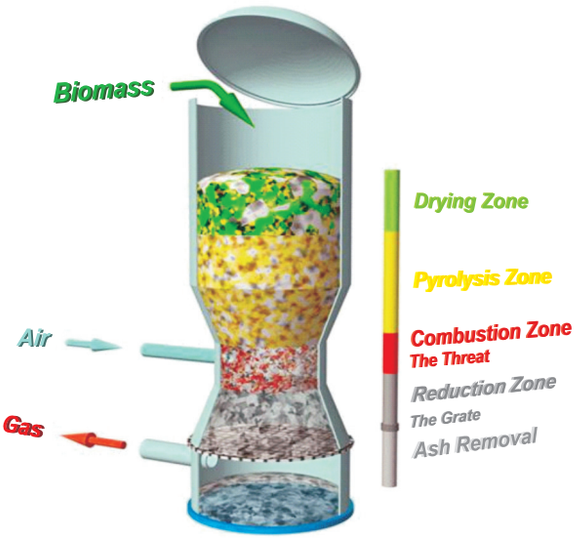


Figure 11.16 Gasifier

The following reactions take place in the biomass gasification.

$C + O_2 = CO_2$

$H_2 + 1/2\ O_2 = H_2O$ **Exothermic Reaction**

When these gases passes through bed of biomass converted charcoal in the reduction zone, the following main reactions takes place:

$C + CO_2 = 2CO$

$C + H_2O = CO + H_2$ **Reduction Reaction**

$CO_2 + H_2 = CO + H_2O$ **Water Gas Reaction**

$C + 2H_2 = CH_4$ **Methanation Reaction**

Typical Producer Gas Composition

CO = 19 ± 3 %	CH_4 = 03 ± 1%
H_2 = 18 ± 2%	CO_2 = 10 ± 3%
N_2 = 50 ± 2%	

Average conversion efficiency of a gasifier is given by the following formula:

$$\eta_{Gas} = \frac{\text{Calorific value of gas/kg of fuel}}{\text{Avg. calorific value of 1 kg of fuel}}$$

Example:

1 kg of wood produces 2.5 m^3 of gas with average calorific value of 1000 kcal/Nm^3. Average calorific value of wood (dry) is 3500 kcal/kg.

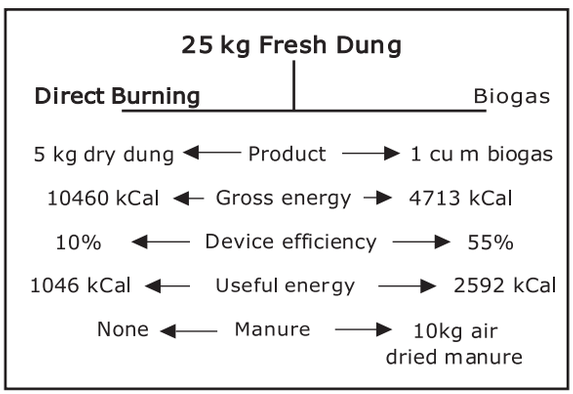
Hence

$$\eta \text{ Gas} = \frac{2.5 \text{ } (m^3/\text{kg of wood}) \text{ x } 1000 \text{ kcal}/m^3)}{3500 \text{ kcal/kg of wood}} = 71\%$$

Spark ignition engines running on producer gas on an average produces 0.55-0.75 kWh of energy from 1 kg of biomass. Compression ignition (diesel) engines cannot run completely on producer gas. Thus to produce 1 kWh of energy they consume 1 kg of biomass and 0.07 litres of diesel. Consequently they effect 80-85% diesel saving.

Biomethanation of Biomass (Anaerobic Process)

Biomass can also be converted into bio-methane gas which is composed mainly of methane and carbon dioxide. The process is based on biological digestion / anaerobic digestion (biomethanation) of biomass. This is the only process giving additional advantage of high grade manure as the by-product. The raw materials for biomethanation process include manure, sewage sludge, municipal solid waste, fruit and vegetable waste, food waste, distillery wastes and other biodegradable wastes. Bio-methane can completely replace natural gas for applications using natural gas such as boilers, furnaces, IC engines etc.



Biomass offers higher energy efficiency through form of biogas than by direct burning (refer chart). Biogas produced through anaerobic process (in the absence of air) using cow dung as input material is generally called as Gobar gas. The gobar gas is a gas mixture typically comprising of around 60% methane and 40% carbon dioxide that is formed when organic matter such as dung, industrial organic wastes,

vegetable wastes etc. are broken down by specific bacteria in the absence of air, at slightly elevated temperatures (most optimum between 35 - 40°C). The biogas process is also known as anaerobic digestion or fermentation, and provides a clean fuel that can be produced on a scale varying from a small household system to a large commercial plant of several thousand cubic metres. Biogas can be used for electricity generation or purified to be used as a vehicle fuel.

Anaerobic digestion is a four-stage process as specific bacteria feed on certain organic materials. In the first stage, acidic bacteria dismantle the complex organic molecules into smaller molecules and in the second stage, these molecules further breakdown into organic acids, carbon dioxide and ammonia. A second type of bacteria (methanogenic bacteria) starts to convert these molecules into acetates and hydrogen in the third stage, which then converts to methane in the fourth stage. These methane producing bacteria are particularly influenced by the ambient conditions, which can slow or halt the process completely if conditions are not favourable.

A typical biogas plant using floating drum biogas prevalent in India is described in Figure 11.17. This design consists of a tank or a well with a partition wall to prevent mixing of influent fresh dung slurry with the outgoing spent slurry. The gas produced is trapped under a plastic or a metallic drum. With the continuous production more gas is trapped under this bell and the drum rises. This acts as a gas storage unit and when the tap above is released, the gas is discharged at more or less constant pressure.

A non-return valve in the outlet is a valuable investment to prevent air being drawn into the digester, which would destroy the activity of the bacteria and provide a potentially explosive mixture inside the drum.

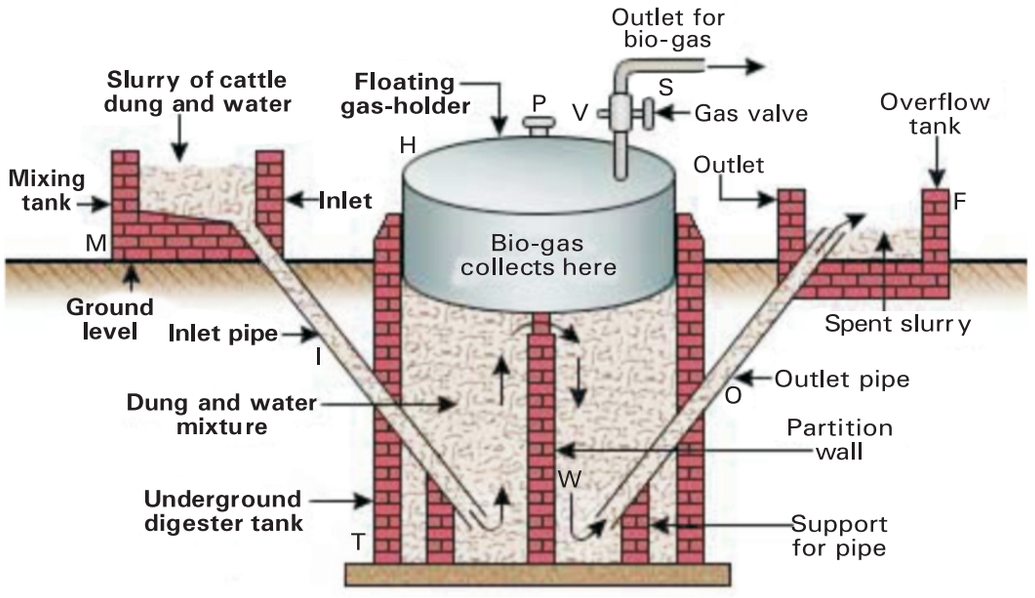


Figure 11.17 Biogas Plant

Biofuels from Biomass

Biomass can be converted into liquid fuels such as Ethanol and Biodiesel to partially replace the conventional petroleum fuels.

Ethanol is commonly produced by the fermentation of molasses, a by-product in sugar manufacture.

It is also produced by fermenting any biomass feedstock rich in carbohydrates (starch, sugar or cellulose). e.g.: Sugar beet, Sweet corn and Ligno-cellulosic materials (straw and wood waste), which are much cheaper than molasses, are now being considered for manufacturing ethanol. Ethanol is used as a fuel additive to cut down vehicle's carbon monoxide and other smog causing emissions. Flexible fuel vehicles, which run on mixture of gasoline, use up to 85% ethanol.

Biodiesel is a good alternative for diesel. The most economical way of producing biodiesel is by transesterification of extracted oil (e.g. Jatropha seeds oil) with alcohol such as methanol. Jatropha is a non edible tree-borne oilseed which grows in dry and arid land. Biodiesel can be used as an additive to reduce vehicle emissions (typically 20%) or in its pure form as a renewable alternative fuel for diesel engines. All oils extracted from plant origin, waste cooking oil and animal fat can be used as raw materials for biodiesel production. The biodiesel cycle is shown in Figure 11.18.

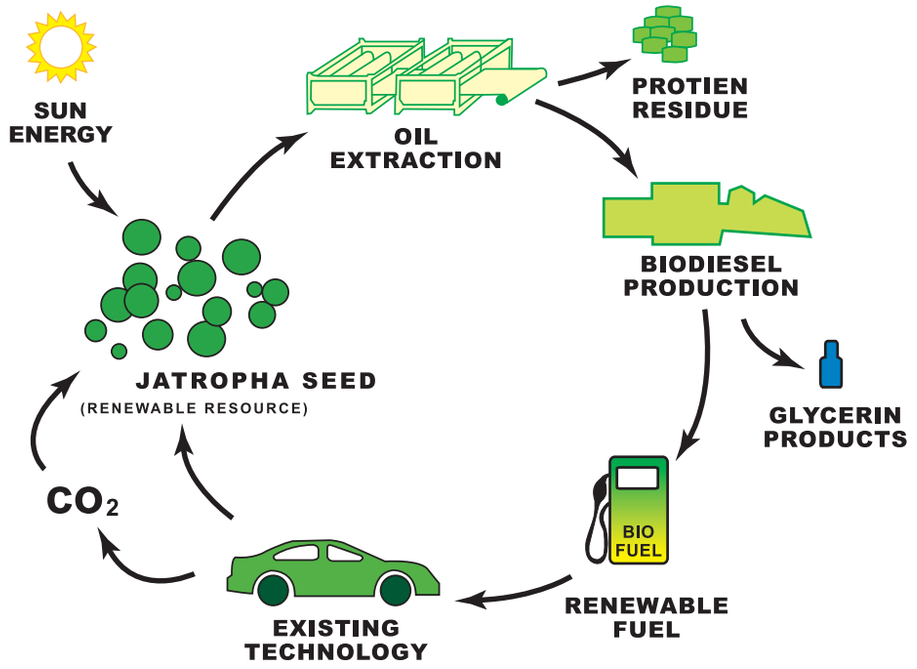


Figure 11.18 Biodiesel Cycle

11.7 Hydro Power

Water power can be harnessed in many ways; the most common way is to use a turbine which is turned by water moving in a controlled manner. Large dams hold water which can be used to provide energy

for industry and grid electrification systems. Smaller systems can provide energy to remote regions without the need to build dams. Classification of hydro by size is given in the Table 11.2.

Table 11.2 Classification of Hydropower by Size

Large- hyro	More than 25 MW and feeding into utility grid
Small-hydro	2001 kW - 25 MW - usually feeding a grid
Mini-hydro	101 kW to 2 MW; either stand-alone or feeding a grid
Micro-hydro	From 11 kW up to 100 kW; usually providing power for remote areas away from the grid
Pico-hydro	From a few hundred watts up to 10 kW

Micro-hydro power is the small-scale harnessing of energy from falling water; for example, harnessing enough water from a local river to power a small factory or village. The Figure 11.19 shows the main components and layout of a run-of-the-river micro-hydro scheme. This type of scheme requires no water storage but instead diverts some of the water from the river which is channelled along the side of a valley before being 'dropped' into the turbine via a penstock.

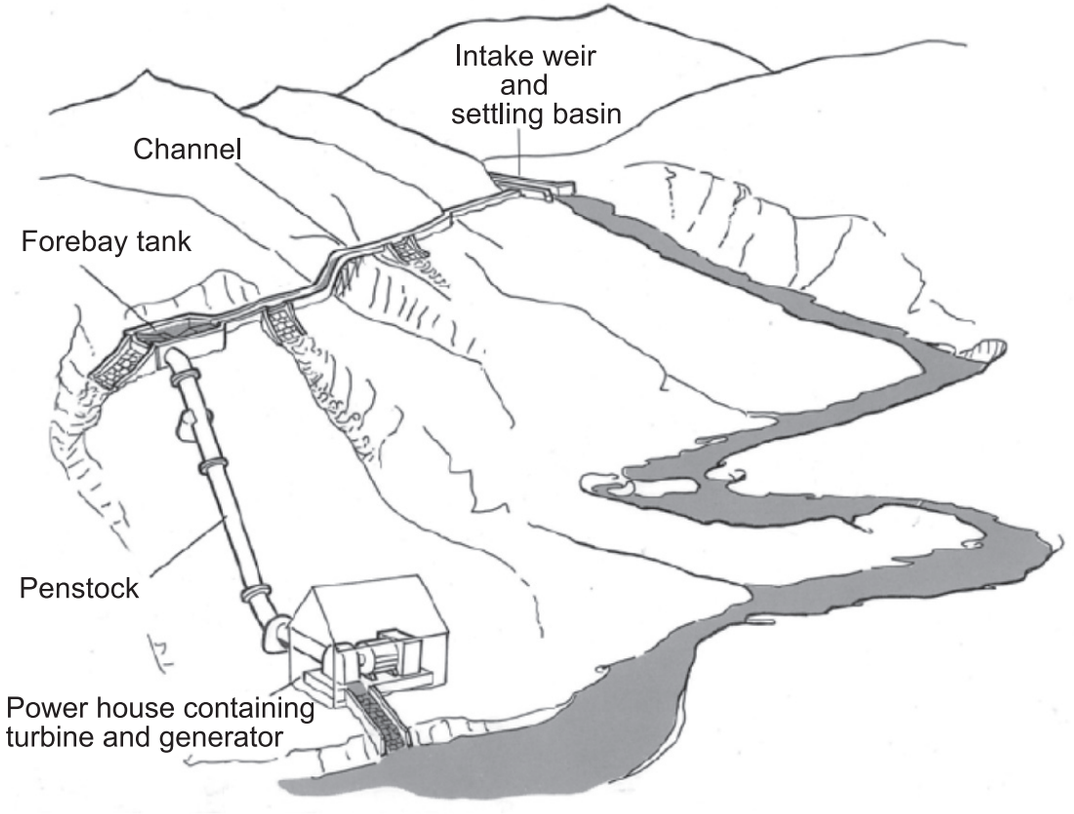


Figure 11.19 Main Components and Layout of a run-of-the river Micro-hydro Scheme

Water into Watts

To determine the power potential of the water flowing in a river or stream it is necessary to determine both the flow rate of the water and the head through which the water can be made to fall. The potential power can be calculated as follows:

Theoretical power (P) = Flow rate (Q) x Head (H) x Gravity (g)

Where, Q is in cubic metres per second, H in metres and g = 9.81 m/s^2 then,

P = 9.81 x Q x H (kW)

Small water turbines rarely have efficiencies better than 80%. Power will also be lost in the pipe carrying the water to the turbine, due to frictional losses. A rough guide used for small systems of a few kW rating is to take the overall efficiency as approximately 50%. Thus, the theoretical power must be multiplied by 0.50 for a more realistic figure.

Example: A turbine generator set operating at a head of 10 metres with flow of 0.3 cubic metres per second will deliver approximately, (9.81 x 0.5 x 0.3 x 10 =) 14.715 kiloWatts of electricity.

How much power generation potential is available in a run of river mini hydropower plant for a flow of 20 litres/second with a head of 12 metres. Assume system efficiency of 60%.

Power = Head x Flow x Gravity

$$= \frac{12 \times 20 \times 9.81 \times 0.6}{1000} = 1.4 \text{ kW}$$

11.8 Fuel Cell

Input to a Fuel Cell is hydrogen. Hydrogen combines with oxygen to produce electricity through an electrochemical process with water and heat as by-products. Since conversion of the fuel to energy takes place using an electrochemical process (not combustion process), fuel cell is a clean, quiet and highly efficient process. Although there are many types of fuel cells, the principle of operation is similar.

Operation of Fuel Cell

A Fuel Cell (Figure 11.20) consists of two catalyst coated electrodes surrounding an electrolyte. One electrode is an anode and the other is a cathode. The process begins when hydrogen molecules enter the anode. The catalyst coating separates hydrogen's negatively charged electrons from the positively charged protons. The electrolyte allows the protons to pass through to the cathode, but not the electrons. Instead the electrons are directed through an external circuit which creates electrical current. While the electrons pass through the external circuit, oxygen molecules pass through the cathode. The oxygen and the protons combine with the electrons after they have passed through the external circuit producing water and heat.

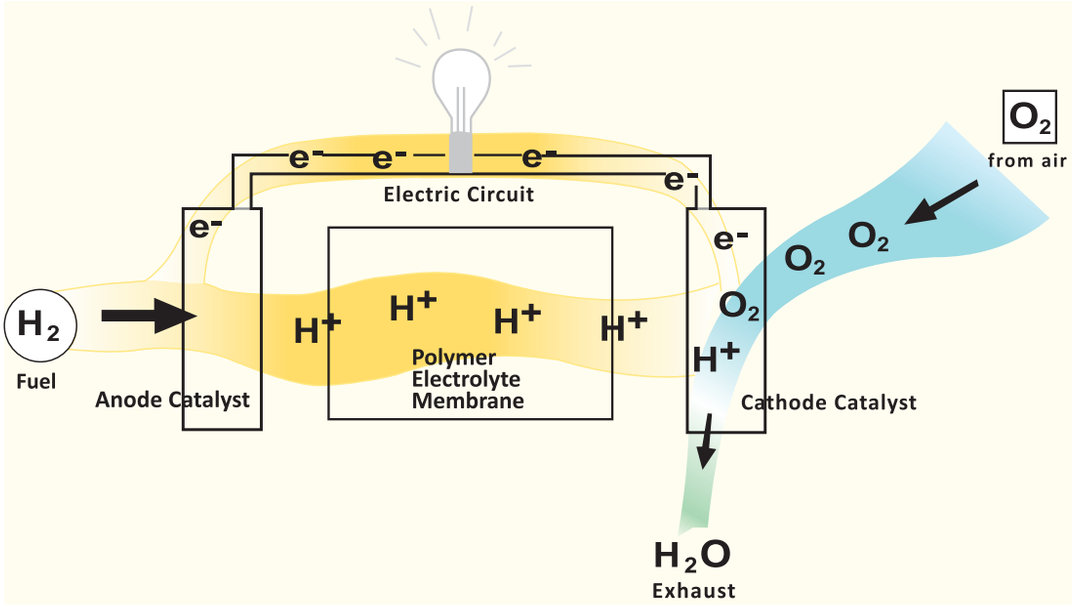


Figure 11.20 Fuel Cell

Individual fuel cells can then be placed in a series to form a fuel cell stack. The stack can be used in a system to power a vehicle or to provide stationary power to a building.

In general all fuel cells have the same basic configuration - an electrolyte and two electrodes. Whatever be the type of fuel cell, all require hydrogen as fuel. Hydrogen is a secondary energy resource, meaning it must be made from another fuel. Hydrogen can be produced in a variety of ways such as steam reforming of natural gas, electrolysis of water, gasification of biomass, etc. The biggest hurdle to large scale commercial exploitation of fuel cell is the cost of production of hydrogen which is now very high.

Table 11.3 Types of Fuel Cells

S. No.	Type	Anode	Cathode	Electrolyte	Remarks
1	Proton Exchange Membrane Fuel Cell (PEMFC)/ Polymer Electrolyte Membrane Fuel Cell	Hydrogen	Oxygen	Water-based, acidic polymer membrane	• High-temperature variants use a mineral acid-based electrolyte and can operate up to 200°C. • Electrical output can be varied, ideal for vehicles • Use a platinum-based catalyst on both electrodes • Have high power density

2	Direct Methanol Fuel Cells – DMFC	Methanol	Oxygen	Electrolyte: polymer membrane (like PEMFC)	• Use a platinum–ruthenium catalyst on the anode and a platinum catalyst on the cathode • Operate in the range from 60°C to 130 °C • Direct use of methanol avoids use of fuel vaporizers, heating and humidification requirements • DMFC are convenient for portable power applications with outputs generally less than 250 W
3	PAFC – Phosphoric Acid Fuel Cells	Hydrogen	Oxygen	Electrolyte: liquid phosphoric acid in a bonded silicon carbide matrix	• Use a finely dispersed platinum catalyst on carbon • Quite resistant to poisoning by carbon monoxide • Operate at around 180 °C. • Electrical efficiency is relatively low, but overall efficiency can be over 80% if the heat is used • Used in stationary power generators (100 kW to 400 kW)
4	Alkaline Fuel Cells – AFC	Hydrogen	Oxygen	Electrolyte: alkaline solution such as potassium hydroxide in water	• Commonly use a nickel catalyst • Generally fuelled with pure hydrogen and oxygen as they are very sensitive to poisoning • Typical operating temperatures are around 70 °C • Can offer high electrical efficiencies • Tend to have relatively large footprints • Used on NASA shuttles throughout the space programme

5	SOFC – Solid Oxide Fuel Cells	Synthesis gas (Hydrogen & carbon monoxide)	Oxygen	Electrolyte: solid ceramic, such as stabilised zirconium oxide	• Has solid state anode and cathode • Can run on hydrocarbon fuels such as methane • Operate at very high temperatures, around 800 °C to 1,000 °C • Best run continuously due to the high operating temperature • Popular in stationary power generation
6	Molten Carbonate Fuel Cells – MCFC	Synthesis gas (Hydrogen & carbon monoxide)	Oxygen Carbon Dioxide	Electrolyte: a molten carbonate salt suspended in a porous ceramic matrix	• Can run on hydrocarbon fuels such as methane • Operate at around 650 °C • Best run continuously due to the high operating temperature • Most fuel cell power plants of megawatt capacity use MCFCs, as do large combined heat and power plants

Applications of Fuel Cells

The type of fuel cells used is decided by the application in which it is used. Since fuel cells are capable of producing power anywhere in the 1 Watt to 10 Megawatt range, they can be applied to almost any application that requires power.

The low power range fuel cells can be used as source of power for personal electronics applications such as charging of cell phones, personal computers etc. The high power fuel cells (1 kW – 100 kW range) fuel cell can be used to power vehicles. The megawatt range fuel cells can be used to convert energy for distributed power uses. Application of fuel cells in the transportation sector has significant advantages like reduced complexity of design.

11.9 Energy from Wastes

Energy can be recovered from wastes (trash) via combustion of waste in incinerators and generating power. A typical Waste-to-Energy power plant using direct combustion is explained in Figure 11.21.

Power generation from landfill gas

Biogas produced from landfill is known as Landfill gas (Figure 11.22). This process is also an anaerobic digestion process as bacteria decompose organic matter naturally in absence of oxygen over time. Landfill gas is composed mainly of methane and carbon dioxide. The methane gas produced in landfill sites normally escapes into the atmosphere and contributes to greenhouse gas emissions. However, if perforated pipes are inserted into the landfill, the landfill gas will travel through the pipes under natural pressure to be used as energy source.

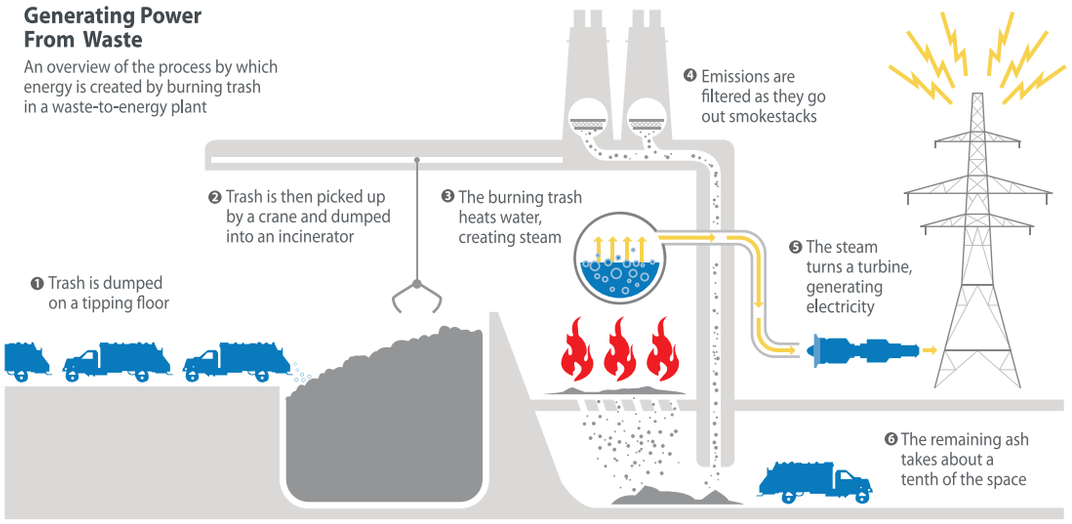


Figure 11.21 Energy from Wastes

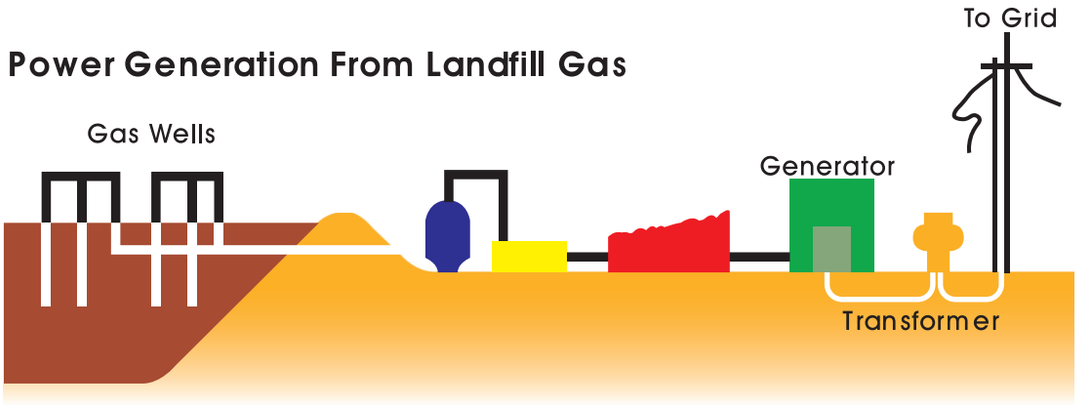


Figure 11.22 Power Generation from Landfill Gas

11.10 Wave Energy

Sea waves are the result of the concentration of energy from various natural sources like sun, wind, tides, ocean currents, moon, and earth rotation. Waves originate from wind and storms far out to sea and can travel long distances without significant energy loss, and hence power production is much steadier and more predictable. Unlike the wind and solar, power from sea waves continues to be produced round the clock.

Wave energy contains roughly 1000 times the kinetic energy of wind. Hence it allows smaller devices to produce power. Wave energy varies as the square of wave height whereas wind power varies with the cube of air speed. Water being 850 times as dense as air results in much higher power produced from wave averaged over time. Theoretically it is possible to extract 40 MW of power per km of coast

where there are gentle waves (say 1 m height) and 1000 MW per km of coast where the wave height is 5 m.

Kinetic energy from waves can be used to power a turbine. As shown in the Figure 11.23, the wave rises into a chamber. The rising water forces the air out of the chamber. The moving air spins a turbine which can turn a generator. When the wave goes down, air flows through the turbine and back into the chamber through doors that are normally closed thus generating power even when wave is receding.

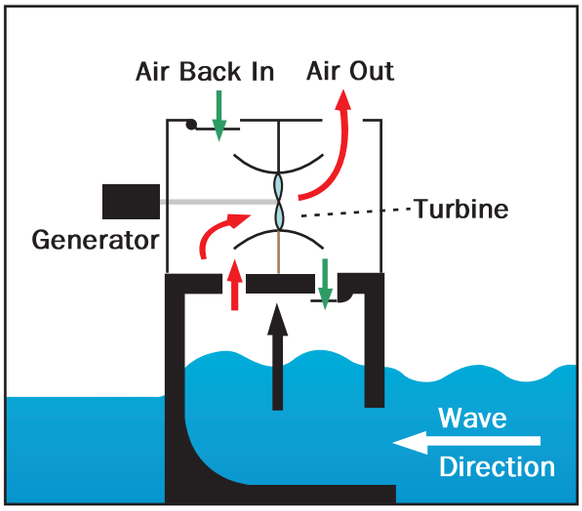


Figure 11.23 Wave Energy

11.11 Tidal Energy

How tide is caused?

Tidal energy is another form of ocean energy. Tides are generated by the combination of the moon and sun's gravitational forces. Greatest effects of tides are in spring when sun and moon combine forces. Bays and inlets amplify the tide. Cycles of low and high tides occur twice a day. When tides come into the shore, they can be trapped in reservoirs behind dams. Then when the tide drops, the water behind the dam can be let out just like in a regular hydroelectric power plant. In order for the tidal energy to be practicable for energy production, the height difference needs to be atleast 5 m is needed. The principle of working of tidal energy is shown in Figure 11.24.

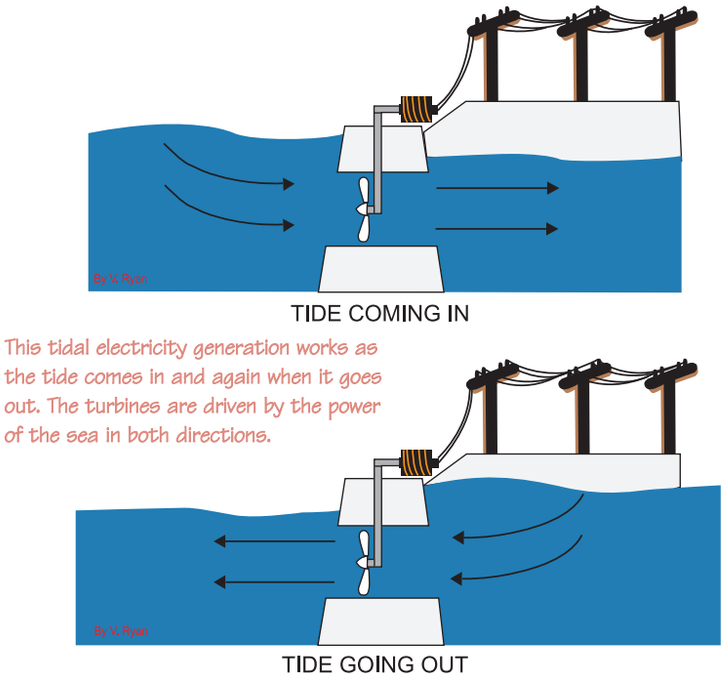


Figure 11.24 Tidal Energy

11.12 Geothermal Energy

The top most part of the earth is the crust. Below the crust of the earth is a layer called mantle. The top layer of the mantle is a hot liquid rock called magma (see Figure 11.25). The crust of the earth floats on this liquid magma mantle. When magma breaks through the surface of the earth in a volcano, it is called lava.

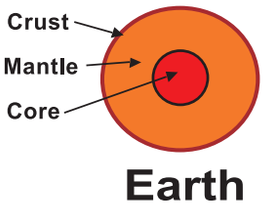


Figure 11.25 Geothermal Source

For every 100 meters you go below ground, the temperature of the rock increases about 3°C. So, at a depth of about 3000 metres below ground, the temperature of the rock would be hot enough to boil water. Deep under the surface, water sometimes makes its way close to the hot rock and turns into boiling hot water or into steam. The hot water can reach temperatures of more than 148°C. When this hot water comes up through a crack in the earth, it is known as hot spring.

Some of the areas have so much steam and hot water that it can be used to generate electricity. Holes are drilled into the ground and pipes lowered into the hot water. The hot steam or water comes up through these pipes from below ground. A geothermal power plant is like in a regular power plant except that no fuel is burned to heat water into steam. Different types of geothermal power plants are described as follows:

Dry Steam Power Plants

A dry steam power plant (Figure 11.26) draws steam from a hydrothermal production well and sends it to a turbine/generator. The steam turns the turbine to generate electricity and is then condensed and returned to the geothermal reservoir via an injection well.

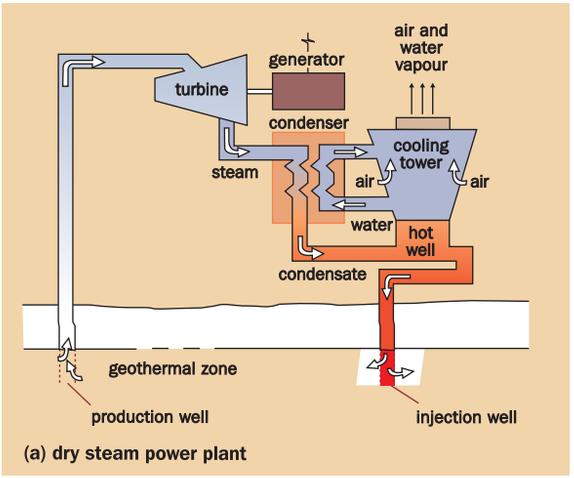


Figure 11.26 Dry Steam Power Plant

Flash Steam Power Plants

Flash Steam Power (Figure 11.27) draws hot water from a hydrothermal production well to a flash tank where a drop In pressure "flashes" the hot water (182°C) to steam. The steam turns a turbine/generator that generates electricity. The steam is then condensed and along with the remaining hot water not flashed into steam is returned to the geothermal reservoir via an injection well.

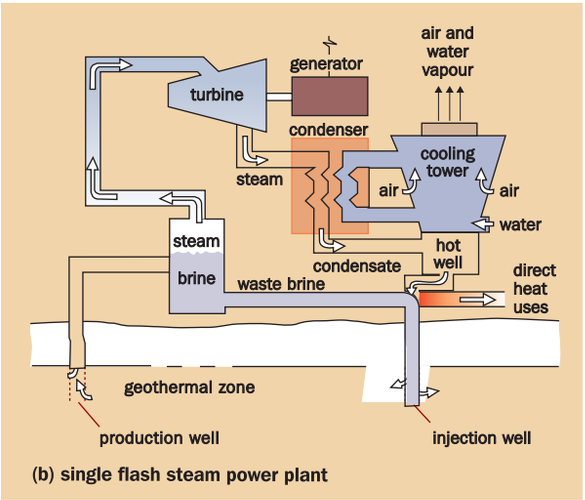


Figure 11.27 Flash Steam Power Plant

Binary Cycle Power Plant

Binary Cycle Power Plants (Figure 11.28) operate on the lower-temperature waters, 107° to 182°C). These systems use two closed loops. Binary cycle pumps hot water from well to a heat exchanger where hot water is used to heat a working fluid, usually organic compound with low boiling point.

This working fluid is then vaporized in a heat exchanger and used to turn a turbine. The geothermal water and the working fluid are confined to separate closed 1oops. So there are no emissions into the air.

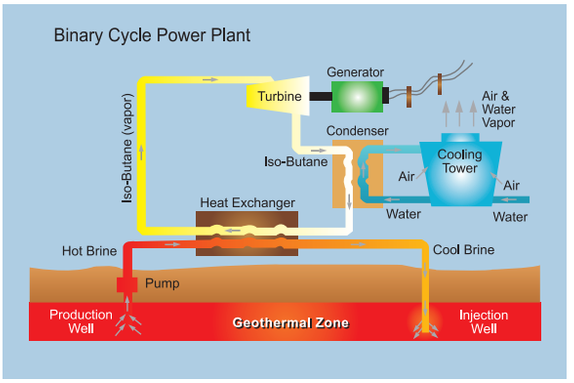


Figure 11.28 Binary Cycle Power Plant

Solved Example:

Find out the conversion efficiency of a gasifier, if 20 kg of wood (having a calorific value of 3200 kcal /kg) produces 46 m^3 of producer gas having an average calorific value of 1000 kcal / Nm^3.

Ans:

Heat Input in the Gasifier	= 20 x 3200 = 64000 kcal
Heat Output as Producer gas	= 46 x 1000 = 46000 kcal
Conversion efficiency of Gasifier	= Heat Output / Heat Input = 46000 x 100 / 64000 = 71.88 %

QUESTIONS	
Objective Type Questions	
1.	Which among the following raw material is used for biodiesel production? a) leaves b) corn c) animal and vegetable fat d) coal
2.	A non-renewable energy resource: a) can be plugged in and recharged b) will eventually run out c) will not work for new appliances d) can be used over again
3.	The rotor blades start to rotate a) at cut-in speed b) cut-out speed c) rated speed e) furling speed
4.	If wind speed doubles, energy output from wind turbine will be a) 2 times higher b) 4 times higher c) 6 times higher d) 8 times higher
5.	Solar constant is _____. a) 342 W/m^2 b) 1368 W/m^2 c) 1342 W/m^2 d) 1380 W/m^2
6.	A solar cell is made up of _____. a) silicon b) titanium c) magnesium d) teflon
7.	The molten material mixed with gases in the mantle of the earth is called _____. a) core b) lava c) geyser d) magma
8.	What is wind? Which statement is correct? a) wind is the product of temperature differences between atmosphere and stratosphere b) wind is the product of air pressure differences in the atmosphere, due mainly to solar radiation disparities c) wind is the movement of air caused by beating wings of birds d) wind is air movement caused only by earth rotation
9.	Typical efficiency of solar cell is a) 10-15% b) 25 % c) 50% d) 75%
10.	The producer gas is basically a) only CH_4 b) CO and CH_4 c) CO, H_2 and CH_4 d) only CO and H_2
Short Type Questions	
S-1	Why solar cell efficiency is very low?
S-2	What is capacity factor in wind turbine?
S-3	What is the basic requirement for tapping tidal energy?
S-4	Explain the term Betz limit?
S-5	Why evacuated tube collector is more efficient than flat plate collector?
Long Type Questions	
L-1	Explain the operation of a fuel cell with a sketch?
L-2	List and explain various components of a typical wind turbine?

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